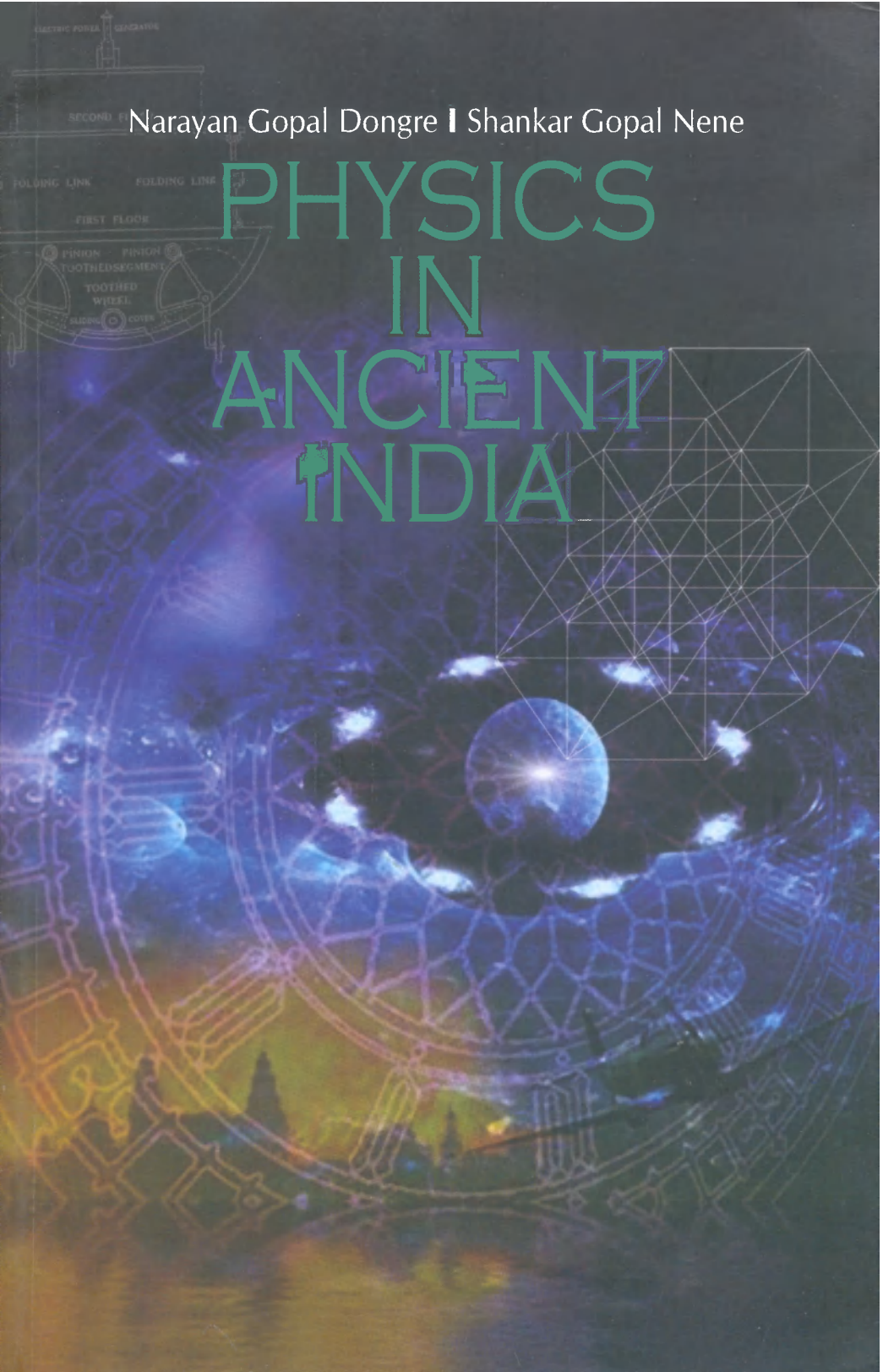
Narayan Gopal Dongre | Shankar Gopal Nene

PHYSICS IN ANCIENT INDIA



Dr N G Dongre (1939-2009), a noted scientist and professor of physics, was a pioneer in the field of ancient Indian science. Widely published, Dr Dongre is the author of many articles and research papers in the area of modern physics as well as in the field of ancient Indian scientific wisdom, in reputed research journals including *Journal of History of Science* (Indian National Science Academy, New Delhi). Dr Dongre participated in many science conferences and presented papers on Science and Technology in India.

Dr Shankar Gopal Nene, Sahityacharya, Kavyatirtha, MA in Sanskrit, Hindi-Pali and Linguistics is proficient in many languages. Dr Nene has authored several books as well as translations in Hindi, Sanskrit and English including T. Burrow's famous work the *Sanskrit Language* into Hindi in collaboration with Late Bholashankar Vyas. For his Hindi translation of the book *Lal Bahadur Shastri: Life of Truth in Politics*, he has received a special mention from former Prime Minister Atal Bihari Vajpayee. He has edited several volumes of research projects and presented papers in many workshops and seminars across India on Vedic studies. He was the chief editor of *The Contacts*, a monthly journal published from Frankfurt, and Deputy Secretary of Europa Indian Foundation, Germany. Dr Nene has authored critical editions of the manuscripts on various oriental subjects. He is a visiting scholar at the Centre of Advanced Studies in Sanskrit (CASS), Pune University and teaches Manuscriptology. He has made a significant contribution along with Dr N G Donge in the field of research connected with the opportunities and potentials of scientific investigations in ancient Indian knowledge systems.

Popular Science

Physics in Ancient India

(Gaṇita-vaiśeṣikaṁ)

Narayan Gopal Dongre

Shankar Gopal Nene

nbt.india
एक भूते सकलम्

NATIONAL BOOK TRUST, INDIA

ISBN 978-81-237-7973-7

First Edition 2016 (Saka 1938)
© Shankar Gopal Nene

Published by the Director, National Book Trust, India
Nehru Bhawan, 5 Institutional Area, Phase-II
Vasant Kunj, New Delhi-110070
Website: www.nbtindia.gov.in

Contents

	Preface	*ix*
	Acknowledgements	*xix*
1.	**Quest of Physics**	**1**
	1.1 Introduction	1
	1.2 The Nature of *Vaiśeṣika* and Physics	2
	1.3 *Vaiśeṣika* as Physical and Metaphysical Science	3
	1.4 *Vaiśeṣika*: The New Horizon of Physics	3
	1.5 *Gaṇita Vaiśeṣikam:* The Mathematical Interpretation of *Vaiśeṣika*	4
	1.6 *Jyotiṣam* (Astronomy): Physics of Celestial Bodies	5
	1.7 Conclusion	5
2.	**Indian Philosophy and Physics**	**8**
	2.1 Indian Philosophy	8
	2.2 The Need of Mathematics in Physics	9
	2.3 Definition of Physics	10
3.	***Padārtha*: The Physical Quantity**	**11**
	3.1 *Padārtha* and its Counterpart	11
	3.2 *Vaiśeṣika* as Material Science	12
	3.3 The Six *Padārthas* of *Vaiśeṣika*	12
4.	***Dravyam:* The Basic Physical Quantity**	**16**
	4.1 *Pṛthvī, Apa, Vāyu* (Solid, Liquid and Gas)	16
	4.2 *Aṇu, Dvyaṇuka* and *Trasareṇu* (Atom, Molecule and Smallest Colloidal Particle)	18

4.3 *Pīlupākavāda* (Dalton's Theory of Chemical Reaction) 18
4.4 Tyndall Effect in *Vaiśeṣika* and the Size of the Atom 19
4.5 *Teja* (Energy) 20
4.6 *Ākāśa* (Plasma) 20
4.7 *Bhūta, Dik, Kāla* (The Fundamental Physical Quantities: Mass, Length and Time) 21
4.8 A Tabular Comparision of *Vaiśeṣika 'Dravya'* and Physical Quantities 22

5. *Guṇāḥ*: Properties of Fundamental Physical Quantities 26
5.1 Introduction 26
5.2 *Sāmānya Guṇāḥ* (General Properties) 28
5.3 *Viśeṣa Guṇāḥ* (Specific Properties) 28
5.4 Measurements in Physics 28
5.5 *Dik Parimeyatva* (Measurement of Length) 28
5.6 *Saṅkhyā* (Number) 30
5.7 *Gaṇitam* (Mathematics) 30
5.8 *Pārthivamānaṁ* (Measurement of Mass) 31
5.9 *Kāla* (Time) 31

6. *Dikparimeyatvam*: Length Measurement 34
6.1 Units and Derived Units of Length 34
6.2 Measurement of a Straight Line 35
6.3 Measurement of a Curved Line 36
6.4 Measurement of Area 37
6.5 Measurement of Volume *(Ghanaphaala Māpanam)* 37
6.6 Other Precise Instruments for Measuring Length 40

7. *Pārthwaparimeyatvam*: Measurement of Mass 43
7.1 Introduction 43
7.2 Units and Derived Units of Mass 45
7.3 Scientific Investigation 46

7.4 Indian, Greek, Persian and Roman Weight Standards 48
7.5 *Tulā* (Balance) 51
7.6 The Principle of Balance 51
7.7 The Balance of Kauṭilya 52
8. *Abvimarśaḥ*: *The Liquid* State 57
9. *Vāyuvimarśaḥ*: Gaseous State 59
10. *Kālaparimeyatvam:* Time Measurement 61
10.1 Units of Time 61
10.2 *Nākṣatradinaṁ* (Sidereal Day) 62
10.3 *Sāvandina or Kudina* (Solar Day) 63
11. *Karma* and Its *Sūtras*: Motion and Newton's Equations of Motion 66
11.1 *Karma* (Motion) 66
11.2 The Causes of Karma 67
11.3 Velocity *(Gati)* 67
11.4 Newton's Equations of Motion 67
12. *Vega Saṁskāra*: Mechanical Force and Newton's Laws of Motion 71
12.1 *Saṃskāra (Force)* 71
13. *Sthitisthāpakatā Saṁskāra:* Elasticity 75
13.1 *Sthitisthāpakatā* 75
13.2 Linear Elasticity 75
14. *Gurutvavimarśaḥ*: Gravity and Gravitation 78
14.1 *Gurutva* (Gravity) 78
15. *Śabda*: Wave Aspect 87
15.1 *Śabda* 87
16. *Teja*: Energy 90
16.1 *Teja* 90
16.2 Sources of Energy 90

17. *Sāmānya, Viśeṣa, Samavāya* and *Abhāva:*
The Mathematical Expressions **92**

17.1 *Sāmānya* (Set) 92

17.2 *Viśeṣa* (Specific) 93

17.3 *Samavāya* (Concomitance) 94

17.4 Ancient Scale of Temperature: *Liṅka* 97

17.5 *Abhāva* (Absence) 100

Appendix I 105

Appendix II 107

Preface

It is my pleasure to put this thoroughly revised and updated edition of *Physics in Ancient India* in the hands of readers with the hope that this will also receive the same response and accolades from the scholars as the last edition.

In India, the study of Vedas and other ancient scriptures related to various philosophies and spiritual knowledge done till today through popular means has been more or less complete and exhaustive. However, it has been observed that the studies of scriptures related to physical subjects such as astronomy, medicine, chemistry, engineering etc. have never been given due consideration and importance. At the same time, thorough research work, that some of the ancient scriptures related to above mentioned topics demand, has never been undertaken. For example the treatise on '*Vaiśeṣika Darśana*' by Maharṣi Kaṇāda, which is, more or less, a 'Book of Physics' has never been studied the way it should have been. As far as some of the scriptures related to philosophical knowledge in ancient Indian thoughts are concerned; a number of descriptions, notes, comments and critical studies are available to establish the principles and doctrines posited by these texts. However, in the last 2000 years, no effort has ever been made to establish such principles mathematically. It would have been possible to establish some principles by experimental studies using some equipment; but it is really quite strange to say that such efforts were never made. A Marathi Encyclopaedia compiled and edited by Ketkar and published in 1922, in its section 'History of Physics' especially mentions that it is an 'unwritten page'. None

of the ancient scriptures provides evidence for the existence of physical or material sciences in India. For this reason, and also for the reason mentioned above, for a very long time, there has been a great prejudice that Ancient Indian Knowledge tradition had never laid its hand on physical or material sciences.

Ancient Knowledge Base

Vedas mean knowledge; the Vedas are regarded as the most ancient scriptures in the whole world. Each and every thing related to the life is believed to have been dealt with by the Vedas, as the Vedas, ostensibly, contain the ultimate knowledge. It has been well established by various other ancient scriptures that people of ancient India had a very good knowledge of the various subjects related to science. Some manuscripts related to the period known as 'Sūtra Period' (800-200 BC) have been discovered which clearly show that ancient Indian people had the knowledge of various thoughts and principles related to Chemistry, Physics and Metallurgy. Not only this, they also had the knowledge of conducting 'Practicals' which were required to establish the principles related to the branches of science mentioned above. Here, we will take up this opportunity to discuss about the knowledge ancient Indian people had regarding the material sciences.

***Amśubodhinīśāstra* vis-a-vis Modern Physics and Technology**

Amśubodhinī is one of the works of Sūtra period. These Sūtras were created by Maharṣi Bharadvāja and an interpretation on these Sūtras was written by the commentator Bodhānanda. The original work contained 12 chapters out of which only the first chapter is available under the title '*Jagatśṛṣṭyādhikāraḥ*' ("जगत्सृष्ट्यधिकार") meaning a chapter containing description of cosmology. One copy of this manuscript was procured from the Oriental Learning Institute of Baroda in 1994 by late Dr. Narayan Gopal Dongre and the writer of these lines. So, the study and the research on the above said manuscript had thus begun. The whole chapter was interpreted; and a book by the name *"Maharṣi Bharadvāja's Amśubodhinīśāstram: Cosmology and Physics of Nuclear Particles in Ancient India: A*

Book of Modern Physics and Technology" was published in Pune, in 2010.

The Sūtras of Bharadvāja describe how this universe was created. The description exactly matches with the well accepted description of cosmologist Stephen Hawkins who has earned a great name in the field of modern material sciences. First Sutra: '*Atha kalpasṛṣṭirātmatvāt sūryeṇa*' — 'अर्थ कल्पसृष्टिरात्मत्वात् सूर्येण।' This means that the creation and development of all living and non-living things took place in '*Śwetavārāhakalpa*' through the Sun. Universe of different kinds were created from the primal atom or the *paramāṇu*. The description starts with the primal atom and goes till describing the Big Bang. The whole description is about the creation of the universe which is more or less similar to the views of modern scientists.

Spectrometer or Varṇakramamāpakayantra or ध्वान्तप्रमापकयंत्र and Novel Infrared Transparent Material of range 5000 to 1400^{cm} or प्रकाशस्तंभनाभिदलौह

In *Amśubodhinī*, there are evidences to bear out that some considerably complex instruments and tools existed. One of them was '*Dhvāntapramāpaka yantra*' or ध्वान्तप्रमापकयंत्र which is known as spectrometer in the modern context. '*Dhvāntapramāpaka yantra*' or spectrometer was used for measuring the dispersion of sun-rays. In astrophysics it was used for the spectral classification of *Nakṣatras*. The spectrophotometer devised through modern methods also, more or less, serves the same purpose. The synthesis of materials or alloys required to prepare the lens and windows of the spectrometer was known to the people of ancient India. Both Bharadvāja and Bodhānanda have given descriptions for devising such a spectrometer which was used for analyzing and probing the creation of different star-systems. Late Dr. Narayan Gopal Dongre from Varanasi devised a spectrometer according to the methodology and process described in the Sūtras of Bharadvāja and illustrated by Bodhānanda. The spectrometer was on display and was, till recently, available for inspection in the department of material sciences of

Banaras Hindu University. Now, it has been shifted to Pune. The details of making and other descriptions appearing in the book entitled *Amśubodhinīśāstram*, have also been published in the *Indian Journal of History of Science* published by the National Science Academy, Delhi and is also accessible on Internet.

***Prakāśastambhanābhidalauha*:** Novel Infrared transparent Material of range 5000 to 1400^{cm}. Ancient India had made many advances in the field of metallurgy. One can see such descriptions given in various ancient scriptures. In this context, the synthesis of a very special material—'Infrared transparent Material of range 5000 to 1400^{cm}' is very significant. This material was synthesized by Dr. Narayan Gopal Dongre at the National Metallurgical Laboratory (NML), Jamashedpur with the help of the then Director of the NML and Dr. Dongre's co-workers, with the help of methodology and process prescribed by Bharadvāja. The special property of this material, which is used for creating the widows and prisms is that it is non-hygroscopic in contrast to the other such materials which were earlier used for such purposes. The earlier used materials were losing their infrared transparency in presence of moisture, whereas the novel material which was specially synthesized; retains its properties despite such conditions. At the same time it is also resistant to the rust. It is important to note, this material was synthesized according to the methodology and process given in the Sūtras of Bharadvāja in *Amśubodhinīśāstram*.

Both the materials developed through research are not only unique for their functionality, but also for the obvious evidence which they provide for the in-depth knowledge ancient Indians had in material science and other branches of science.

Besides, Bharadvāja had also given descriptions for the methodology of the synthesis of many other materials and devises. As described above, it also encompasses the synthesis of many optical materials like prisms, windows and lenses. Some of such materials are—*Ūṣṇāpahārakalauha*, *Chāyāpravibhājakalauha* and *Prakāśastambhanābhidalauḥ*, etc. For details please refer *Maharshi*

Bharadwaja's Amshubodhinishastram: Cosmology and Physics of Nuclear Particles in Ancient India: A Book of Modern Physics by Dongre-Nene.

Following lines from the *Sāṅkhya Kārikā* testify this temper of investigative spirit among the ancient Indians:

Dṛṣṭamanumānamāptavacanaṁ ca sarvapramāṇaśiddatvāt trividhaṁ pramāṇamiṣṭaṁ,

(दृष्टमनुमानमाप्तवचनं च सर्वप्रमाणसिद्धत्वात् त्रिविधं प्रमाणमिष्टम् ।)

From all available sources of information, the methodology which clearly emerges is analogous to that followed in 'modern times' - that of observation, information and authoritative expressions.

Logical reasoning and near-accuracy of observation was the fundamental principle of the Indian scientific age. This process probably had its roots even before the sixth century B.C. The Sāṅkhya and the Vaiśeṣika schools had fostered and developed this scientific spirit with their emphasis on direct observation, exact measurement and persistent enquiry. It is, thus, obvious that scientific thought in ancient India, centuries before the European Renaissance, was not only existent, but had already developed.

Speaking about the state of knowledge in ancient India, B.N. Seal observes: "Let us not superciliously dismiss these studies as 'learned lumber'. Astronomy and mathematics of the Hindus were equally advanced, if not less, in comparison to those of Tyco Brahe, Cardan and Fermet; anatomy was equal to that of Vesalius; Hindu logic and methodology was more advanced than that of Ramus and almost equal to Bacon's; the physicochemical affinity was clearer, more rational and more original than that of Van Helmont of Stahl, and the grammar, whether of Sanskrit or Prākṛt, more scientific and comprehensive in the world than that of Bopp Rask and Grimm."

The works of scholars, such as Praśastapāda (3-4 century AD), Āryabhaṭṭa (3 century AD), Brahma Gupta (6-7 century AD), Śabaraswāmī (8-9 century AD), Vācaspatī (9 century AD), Udayana and Śrīdharabhaṭṭa (12 century AD), Bhāskarācārya and Vijñāna Bhikṣu (12 century AD), Guṇaratne (14 century AD), Dāmodara

(16-17 century AD), and the ancient seats of learning such as Takṣaśilā, Vikramaśilā, Nālandā, Kāñcī and Madurai testify to the continuous intellectual activity with the sole aim of acquiring secular knowledge in ancient India. Learned scholars from various countries such as Greece, Persia, Arabia and China regularly visited India to acquaint themselves with the progress and development in various fields of study and, in the process, the Indian scholars picked up details of the intellectual activity in these countries.

In fact, great Indian sages possessed 'authentic' scientific temper and never accepted 'assumptions' unless theoretical and applied validity was proved.

Some commentaries — in fact less in number compared to the the number of commentaries on other schools of Indian philosophy — on the aphorisms on *Vaiśeṣikaśastra* are available. The *Praśastapāda-bhāṣya*, also known as *Padārthadharma-saṁgraha*, is one of the very well-known books of *Vaiśeṣika* School. Śaṅkara Miśra wrote a commentary on the *Vaiśeṣika* known as *Upaskāra*. A Gujarati edition of this commentary with the further annotation entitled *Kaṇādasūtra-vivṛti* by Jayanārāyaṇa Nyāya Pañcānana and a glossary by Candrakānta Bhaṭācārya are available in one volume.

In the 'Sacred Books of the Hindus' Series, an English translation of the above — the sūtras, the commentary by Śaṅkara Miśra, and the extracts from the glossary of Jayanārāyaṇa, together with notes from the commentary of Candrakānta by Nandlal Sinha has been published (1911). Also a book *Founders of Sciences in Ancient India* by Satya Prakash published in 1965 contains one full chapter dedicated to 'Kaṇāda - the first expounder of realism, law of causation and atomic theory'. We have drawn extensively from these sources.

The following works on the Vaiśeṣika School of thoughts would also interest the readers:

1. *Vyomavatī*, a commentary on *Praśastapāda Bhāṣya* by Vyomācārya.
2. *Kiraṇāvalī*, a commentary on *Praśastapāda Bhāṣya* by Udayanācārya.
3. *Kandalī*, a commentary on *Praśastapāda Bhāṣya* by Srīdharācārya,

4. Setu, a commentary on *Praśastapāda Bhāṣya* by Padmanābha Misra.
5. *Kiraṇāvalī Bhāskara*, a commentary on *Kiraṇāvalī* by Padmanābha Mishra.

Professor A.B. Keith wrote a small book (1921) on Indian Logic and Atomism (An exposition of the *Nyāya* and *Vaiśeṣika* Systems). This book also gives an excellent account of some of the main thoughts developed with regard to the concept of matter and atomism of Kaṇāda.

A small book authored by one of the authors of this work, Dr. N G Dongre, *Vaiśeṣika Siddhāntānām Gaṇitīya Paddhatyā Vimarśaḥ* (Published by the Director, Research Institute, Sampurnanada Sanskrit Vishwavidyalaya, Varanasi in 1980) has formed the basis of this work.

Kaṇāda and his Ancestory

It would appear from the distinctive appellation by which Kaṇāda is recognised that he was the son of Ulūka and a descendent of the highly spiritual family of Kaśyapa. He resided at Prabhāsa, probably the modern Prabhosa in the Allahabad district (*Modern Review*, June 1909) and was the disciple of Soma Sharma who was supposed to be an incarnation of Lord Śiva in Paurāṇika times. He lived a 'pigeon life' making two ends meet on the grain particles picked from the streets. That is why he came to be called Kaṇāda, meaning one who feeds upon grain particles. By such austerities, as the legend goes, he pleased the mighty Lord Śiva, Grand Master of Learning. Lord Śiva appeared in the form of an owl (ulūka), and delivered to him the truths about the six *padārthas*, viz., 'Seven Basic Physical Quantities or मूल-सप्त-पदार्थाः' — Quantities or द्रव्याणि, Properties or गुणाः, Motion or कर्म, Set or सामान्य, Specific or ultimate and partlessness or विशेष and Concomitance समवाय. Lord Śiva appointed him to compose a treatise, embodying those truths for the benefit of the world. Thus, the great sage Kaṇāda composed the sūtras or aphorisms of the *Vaiśeṣika* system.

Antiquity of *Vaiśeṣika*

About the popularity and antiquity of Kaṇāda sūtras, there can be no reasonable doubt. The references we find to Vaiśeṣika in the other five principal ancient systems of Vedic philosophy (*Nyāya, Sāṅkhya, Yoga, Pūrva mīmāmsā, Uttara mīmāmsā*) as well as the works such as *Vāyupurāṇa*, *Padmapurāṇa*, and *Devī-bhāgavata* bear impeccable testimony to its antiquity and popularity. It can be laid down with some degree of practical certainty that it's period is about 6th century B.C.

In 1885, Professor Leumann published an article 'The Old Reports on the Schisms of the Jainas', in the *Indische Studien* (XVII, pp. 91-135). Among the various heresies or schools of thoughts mentioned therein, the sixth school was founded by the author of the *Vaiśeṣikasūtras*, of Caulu race, and hence called Chauluga; which perhaps is a degraded form of Aulukya. Jinabhadra also mentions 144 points of the *Vaiśeṣika* system. Jinabhadra's date is fixed by Professor Leumann in the eighth century A.D. Haribhadra, a Brahmana convert to Jainism, in his *Ṣad-Darṣana-Samuccaya-Sūtram*, mentions *Vaiśeṣika-Darśana*. Haribhadra died in 1055 of the Vira era, or Samvat 585, i.e. 528 AD. Lastly, in an account of king Kaniṣka, (85-106 AD) and his great council under Vasumitra and Pūrṇaka, we read that there was, at that time in Kashmira, a Buddhist who is said to have belonged to the *Vaiśeṣika* school. This would prove the existence of the Vaiśeṣika philosophy in the first century AD. This account has been taken from Sumpahi Choijung, and the same evidence indicates that after the death of Kaniṣka, a rich house holder of the name of Jati, who lived at Aśva-Paranta in the north, invited Vasumitra, monk of the Vaiśeṣika school from Maru in the west and another, Ghoṣasangha from Bactria, and supported the native clergy consisting of 300,000 monks for a period of ten years (vide *Journal of Buddhist Text Society*, Vol. I, part 3, p. 19).

From recent researches, the Vaiśeṣika can be estimated to be 6 to 4 century BC. We have just seen the vast range of country and people the *Vaiśeṣika* doctrine spread, and how it was still flourishing

in the midst of insurgent jainism. It is well known that the Vaiśeṣika philosophy was propounded long before the Yoga system of Patañjali, and that the period of Patañjali is fixed in the third century before Christ. Moreover, there is reason to believe that Vaiśeṣika was prevalent prior to the advent of Buddhism, and survived the moral and intellectual revolution wrought by propagandists of the Buddhist school. For *Vaiśeṣika* does not consciously labour under the turmoil of the Buddhist revolution, and although some of its teachings may appear to have reference to the theories of the Buddhist philosophy, it is possible that they have in view only germs of Buddhism latent in the *Upaniṣads* and other older writings or that they have been read into the doctrines of Kaṇāda by commentators and critics. Moreover, *Vaiśeṣika-sūtras* must have belonged to Sūtra period which is, beyond any doubt, 800 BC to 200 BC. Thus, the main source of the present work is ancient, and has been developed by collating a great deal of interesting details pertaining to Physics from other ancient Indian scriptures, too.

The authors are of the opinion that it is wrong to consider everything written in ancient time on scientific subjects as the last word not to be questioned just as it is wrong to ignore all such matters and consider them as belonging to an age of ignorance, without any scientific value. It is essential that such literature be viewed and evaluated objectively and also critically with an open mind. A careful effort has been made to do this, yet the authors do not claim to have done full justice to the subject.

October 2, 2016 —Dr. Shankar Gopal Nene

Acknowledgements

We owe our sincerest gratitude to the galaxy of ancient thinkers – Indians as well as westerners — Rishis, Munis, sages, scholars in the tradition and scientists of contemporary era, whose works form basis for the perceptions and thought-processes deliberated in the present treatise.

The authors are very grateful for encouraging response and suggestions from the numerous scholars in the field. We are also grateful to the authors of several excellent books, papers and articles from which we have drawn substancially. We are grateful to the authorities of Bharat Kala Bhawan, Varanasi and Patna Museum, Patna for providing the necessary photographs and data which were used for the discussion on measurement of mass. Special thanks are due to Prof. A. Natarajan of Sidhidasam University for his valuable suggestions.

This work is the outcome of studies and investigations of nearly 35 years. During these years persistent debate has been an ongoing process. Deviation from accepted traditional thought systems, both in the field of ancient Indian knowledge disciplines and, to a certain extent, in the arena of modern scientific perceptions, kept us on our toes engaging in interactions, including harsh altercations at times, with traditional Sanskrit scholars and contemporary scientists and thinkers. From each of discussions, however, we were benefited and were that much wiser.

These thinkers and scholars have been doyens in their fields and are widely known for their invincible scholarship. Among the traditional scholars we were able to discuss the theme with late Panditraj Rajeshwarshastri Dravid, Varanasi, MM Pandit Dr. Gopinath Kaviraj, Varanasi, Prof. Baldev Upadhyaya, Varanasi, Pt. Hebbar Shastri, Pt. Vishwanath Shastri Datar, Varanasi. We are sincerely grateful to these scholars for their criticism and suggestions. Salute to their memories!

Late Pt. Gopal Shastri Nene, Pt. Badrinath Shukla both from Varanasi, were always there to ignite and inspire our insight. In fact, Pt. Badrinath Shukla was helpful in making us understand intricacies of Vaisheshikashastra, Nyayashastra and Nyaya-vaisheshikashastra. We bow our heads to the memory of these great scholars.

Consultation and discussion with Prof. V.N, Jha, Director, Centre for the Advanced Studies in Sanskrit, Prof. Somnath Nene, BHU, Varanasi helped in formulating some arguments in this treatise — thanks to them.

I am specially thankful to the Chairman of NBT, Shree Bhai Baldevji, who took personal interest in this thought process and agreed to publish even the second revised edition. The first edition was published by The New Age International Publishers Limited, a subsidiary to Wiley Eastern Limited, in 1994. Thanks are due to Ms Surekha Sachdeva who supervised the production of the book.

October 2, 2016 —Dr. Shankar Gopal Nene

1

Quest of Physics

1.1 Introduction

Ever since man has been a creature of this planet, he has, due to his extensive imagination displayed a certain sense of intense curiosity. His inquisitiveness has goaded him to delve into the mysteries of Nature—its originative elements, the causes of creation and the secrets of various internal and external happenings connected with the material and the sentient being. At its nascent stage the scope of this march was limited, but slowly scarcity of knowledge and appropriate devices gave way to direct perception, inference, analogue and authoritative expression *(Pratyakṣa, Anumāna, Upamāna* and *Śabda)* and an innumerable variety of approaches were applied in digging out the well-rooted secrets of Nature; and for the first time our mind gave birth to what we ordinarily call "laws, principles and doctrines describing the originative elements of Nature." In due course, these were further channelised in the form of different schools of philosophy and natural science.

Nevertheless, the unanimity as well as the universality at the root of every subjective classification is so well established that there is hardly any controversy between the two halves of the world—the oriental and the occidental.

The intensive studies of the Vedas, the different schools of philosophy, literary compositions on the metaphysics from ancient times to the present day in India have more or less aimed towards perfection. Yet it does not seem that proper justice has been done to fully develop the topics related to the material world like astronomy, medicine, chemistry,

engineering, etc. It seems that the study of *Vaiśeṣika Darśana*—which may be considered as an analogue of physics—has been restrained at its very adolescent stage. Although its well-established principles derived from direct perception and inference were well-understood in the form of *Sūtras,* commentaries, connotations, explanations, annotations, notes, etc. over the past two thousand years, they have not been nourished with mathematics and planned experimental devices working on the principle of cause and effect.

That is why, it seems, in *Jñāna Kośa*[1], the fifth volume devoted to the history of science, at the beginning of the chapter *History of Physics*, the authors declare that in ancient India the development and progress achieved in the field of physics had not been authoritatively mentioned as such, either in part or detail. Therefore, the authors state that the topic may be considered as an unwritten page in the 'History of Indian Physics' and hence, they proceed with the 'History of Western Physics.' In the light of these findings, this book, based on the author's earlier work[2], is an attempt to study *Vaiśeṣika Darśana* as Physics in Sanskrit literature, applying scientific and mathematical methodology to it. This is an attempt to record the investigations, and acquaint the reader with what the study has discovered.

1.2 The Nature of *Vaiśeṣika* and Physics

The nature of *Vaiśeṣika Darśana* and Physics is the same, as both of them try to answer such questions as: "What is it?," "How is it?" and "Why is it?" Furthermore, certain other relevant questions like: "Who am I?," "Who is that?" etc. are also raised in *Vaiśeṣika Darśana,* and it is said that they do not fall within the purview of physics but in the field of metaphysics. At the same time, the literature on *Vaiśeṣika* available at present never asks the questions leading to measurement like "How much is it?," "How far is it?," etc. Such questions are tackled by physics. Therefore, the methodology adopted in this book, i.e., the transcription of the principles of *Vaiśeṣika Darśana* in mathematical form, not only covers the field of physics but also metaphysics, which, in turn, may bring 'Soul' and 'Mind'

(*Ātmā* and *Mana)* within the realm of physics. The reader is aware of the fact that the modern approach to the study of man is veering round the concept of man as an integrated organism consisting of body, mind and soul; the generally accepted aim of science is to inquire only into the proximate cause and not the ultimate cause. However, the trend of the narration of *Vaiśeṣika Darśana* considers *Ātmā* and *Mana* as entities like matter and energy of physics.

1.3 *Vaiśeṣika* as Physical and Metaphysical Science

Vaiśeṣika considers that the whole world consists of *Padāratha*[3] (*pada* + *artha*), i.e. physical quantity—a technical term used in physics. All physical quantities are further categorised by forming their sets (*sāmānya*), finding the ultimate indivisible parts, viz., partlessness (*Viśeṣa*) and arranging them in the series of concomitance (*Samavāya*), and sometimes by absence (*Abhāva*). All these four are logical physical quantities which skim out the physical quantities of real existence (*Sattājātīya Padārtha*). Physical quantities of real existence are grouped as basic physical quantities (*Dravya*), their properties (*Guṇa*) and motion (*Karma*). A method has been adopted to express these four logical quantities in the form of a mathematical equation; without which the expressions would require the use of intricate language and yet, the whole description remains qualitative only. The usage of such expression of mathematics not only lessens the huge literary space but begins to speak quantitatively as well. In this study, we have applied this methodology to all physical quantities except metaphysical ones, to show and prove how wonderfully *Vaiśeṣika Darśana* is a 'Book of Physics'.

1.4 *Vaiśeṣika*: The New Horizon of Physics

As a science of physical and metaphysical quantities; *Vaiśeṣika Darśana* states through a *Sūtra*[4] (aphorism) that the ultimate knowledge may be attained through the knowledge of similarities and dissimilarities between the physical and metaphysical basic quantities, properties, motion, set, specifics and concomitance produced due to cosmic order *(Dharma)*. It also states that the knowledge of basic physical quantities

is the cause for the knowledge of basic metaphysical quantities. It further explicitly states that the knowledge of self *(Ātmajñāna)* and prognosis of the ultimate sorrow *(Ātyantikaduḥkhanivṛttinidānatvam)*, which ultimately culminate in salvation *(Mokṣa)*, are obtained through the knowledge of physical and metaphysical quantities. Though *Vaiśeṣika* accepts, like any other school of Indian philosophy, that *Mokṣa* (salvation) is the ultimate goal, it is strikingly unique in its emphasis on the knowledge of physical quantities as the very basis of the knowledge of self *(Ātmā)*. If *Vaiśeṣika* is mathematically interpreted and studied in its totality, we believe, without any doubt that it will excel the highly advanced western sciences, in exploring the unrevealed mysteries of the originative elements like the 'soul' and the 'mind'.

1.5 *Gaṇita Vaiśeṣikam:* The Mathematical Interpretation of *Vaiśeṣika*

This book presents a mathematical analysis of all the elements mentioned in *Vaiśeṣika Darśana,* leaving out the metaphysical or cognitive concepts, i.e., *Ātmā* and *Mana.* So far as the basic concepts, terminologies, and their connotations in the two synonymous terms *Vaiśeṣika Darśana* and physics, are concerned, both are one and the same. The only difference is that *Vaiśeṣika* does not put the laws into mathematical forms, and therefore, it could not develop as the modern physics has. It is essential to put its laws in mathematical forms so as to establish that *Vaiśeṣika* of *Kaṇāda* is not different from physics. In this context, it is important to take notice of *Vatsyāyana's* quotation[5] from *Nyāya Bhāṣya.* It is equally applicable to *Vaiśeṣika Darśana.* Physics, being the science of basic material *(Bhautika)* quantities, all materialistic quantities from *Vaiśeṣika Darśana,* other than *Ātmā* and *Mana* (soul and mind), have been discussed, with a note that the method applied may be extented to discuss the metaphysical quantities by bringing them into the realms of biology and psychology. As the knowledge of soul and mind depends on the knowledge of *Bhautika* quantities in *Vaiśeṣika Darśana,* they are materialistic or physical quantities.

According to *Vaiśeṣika*, the physical quantities (*padārtha*), have been classified in two categories: (1) Those of real existence (*Sattājātīya*) and (2) those of logical existence (*Nyāya-śāstrīya*). The categorisation is done on the principle of dependent and independent character (*Ādhārādheya*) of physical quantities. The physical quantities of real existence are *dravya*, *guṇa* and *karma*, and those of logical existence are *sāmānya*, *viśeṣa*, *samavāya* and *abhāva*. Here, it is important to emphasise that a similar categorisation is there in physics. The only salient feature one must bear in mind is that *sāmānya*, *viśeṣa*, *sāmavāya*, and *abhāva* are simultaneously expressed by a mathematical relation, while the basic quantities are *Dravya* (fundamental physical quantities), *Guṇa* (property) and *Karma* (motion).

In ancient India when *Darśanas* were being developed, all the necessary tools of mathematics were available, but it seems that no philosopher made any effort to express the doctrines about the material world in algebraical terms. These tools remained unexplored and unused. Had this mathematical method been brought into practice earlier, the knowledge earned by the westerners in the last three centuries would have been gifted to mankind one and a half millenia earlier.

1.6 *Jyotiṣam* (Astronomy): Physics of Celestial Bodies

The advancement of astronomy in ancient India is an evidence of the existence of well-developed mathematics which described the motion of planets, etc. and the knowledge of physical quantities then known was well utilised by the astronomers. The whole period of creation was calculated by astronomers on the hypothesis that at the beginning of the creation (*Sṛṣṭi*), all the celestial bodies wherever present, will be again realised at the time of complete destruction (*Pralaya*). The time period of this cycle will be the time of '*Sṛṣṭi-pralaya*'. Chapters like *Jyotiṣopaniṣad* of *Sūrya Siddhānta* and other works of astronomy show their dependence on Indian philosophy.

1.7 Conclusion

Thus, it may be said that astronomy is a science which entirely depends on *Darśana* and mathematics. In other words, we can

study only smaller objects or bodies, regarding their motion, forces, etc. in a laboratory, as in physics, whereas astronomy deals with bodies which are much larger, like Sun and planets, and studied at the Nature's laboratory, the Universe itself. Obviously, astronomy is an applied science—a branch of physics or *Darśana*. It may be regarded that physics is an outcome of philosophy (*Darśana*) and mathematics (*Gaṇita*). Thus, the two are mutually inter-dependent.

It is hoped, the present endeavour will enable the reader to taste the oriental flavour of the same dishes which till now had western dressings.

Notes and References

1. Ketkar, S.V., Chief Editor, *Jñāna Kośa*, Vol. V, pp. 506-507, 1922

2. Dongre, N.G., *Vsaiśeṣikasiddhāntānāṃ Ganitīyapaddhatyā Vimarśaḥ* (V.G.V.) *(वैशेषिकसिद्धान्तानां गणितीयपद्धत्या विमर्शः)* Sarasvatibhavan Studies, Vol. XXVI, Director, Research Institute, Sampurnanand Sanskrit Vishvawidyalaya, Varanasi, 1979

3. *"Dharma-viśeṣa prasūtād dravya guṇa-karma-sāmānya-viśeṣa-samavāyānāṃ padārthānāṃ sādharmya-vaidharmyābhyāṃ tattvajñānānniḥśreyasaṃ" ("धर्मविशेषप्रसूताद् द्रव्यगुणकर्मसामान्यविशषेसमवायानां पदार्थानां साधर्म्यवैधर्म्याभ्यां तत्त्वज्ञानान्निः श्रेयसम्")* - *Vaiśeṣika Sūtraṃ*, 1-1-4, p. 2, quoted from V.G.V.

4. The aphorism 1-1-4, quoted in the aobve reference has been futher elaborated in the following manner:

   Kaṇādavaiśeṣika sūtroktadiśā anātmetaravyāvṛttatayā ātmajñanaṃ prati ātmetarayāvat padārthajñānaṃ kāraṇamiti samarthayati, siddhāntayati ca dravya-guṇa-karma-sāmānya-viśeṣa-samavāyānāṃ padārthānāṃ sakalvidha sādharmya vaidharmya viśaye pramāyāḥ ātmatvajñānuguṇatvaṃ ātyantika-duḥkhanivṛttinidānatvaṃ, falatastāvan mokṣakāranatvaṃ ca; tathā(a)pi coktapadārtha-jātasādharmyavaidharmyavivaraṇaprasaṅge(a)ṅgīkaroti sarvathā bhautikī dṛṣṭimityetasyo darśanasyāyamanitarasādhāraṇo mahāṅśca viśeṣaḥ pratibhāti.
   (कणादवैशेषिकसूत्रोक्तदिशा अनात्मेतरव्यावृत्ततया आत्मज्ञानं प्रति आत्मेतरयावत् पदार्थज्ञानं कारणमिति समर्थयति, सिद्धान्तयति च द्रव्य-गुण-कर्म-सामान्य-विशेष-समवायानां पदार्थानां

सकलविध साधर्म्यवैधर्म्यविषये प्रमायाः आत्मत्वज्ञानुगुणत्वं आत्यन्तिक-दुःखनिवृत्तिनिधानत्वं, फलतस्तावत् मोक्षकारणत्वं च; तथापि चोक्तपदार्थजातसाधर्म्यवैधर्म्यविवरणप्रसंगे अंगीकरोति सर्वथा भौतिकी दृष्टिमित्येतस्य दर्शनस्यायमनितरसाधारणो महान्श्च विशेषः प्रतिभाति ।)

5. *Imāstu catasraḥ vidyāḥ pṛthakprasthānāḥ prāṇabhūtāṁ anugrahāyopadiśyante yāsāṁ caturthīyam ānvīkṣīkī nyāyavidyā. Tasyāḥ pṛthakprasthānāḥ saṁśayādayāḥ padārthāḥ teṣāṁ pṛthagvacanamantareṇādhyātmavidyāmātramiyaṁ syāt yathopaniṣadaḥ*

(इमास्तु चतस्रः विद्याः पृथक्प्रस्थानाः प्राणभूतां अनुग्रहायोपदिश्यन्ते यासां चतुर्थीयमान्वीक्षिकी न्यायविद्या। तस्याः पृथक्प्रस्थानाः संशयादयः पदार्थाः तेषां पृथग्वचनमन्तरेणाध्यात्मविद्यामात्रमियं स्यात् यथोपनिषदः) -Vātsyāyana Nyāya Bhāṣya, I-1-1.

2

Indian Philosophy and Physics

2.1 Indian Philosophy

In ancient times India occupied an esteemed and elevated position among its contemporaries in the world, in culture and civilisation with its rich knowledge of science and development of literature, highlighted by the fact that the Vedic literature is the oldest known literature known to the mankind. No wonder, ancient India was looked upon as a lighthouse showing the way to many a troubled thinkers navigating through the ocean of knowledge in their pursuit of truth. However, nowadays many scholars, both from India and outside, wonder whether ancient India has contributed anything at all to physics.

From the *Sūtra* period (8th Century BC)[1] to the present, Indian philosophy has been elaborated by commentaries, explanations, annotations, notes, etc. in various works. The progress in producing the texts on material sciences such as astronomy, biology, chemistry, metallurgy, anatomy, medicine, civil engineering, etc. which was very much there until the eighth century AD, is not evident in later centuries.

Astronomy is an applied branch of physics, and there are a good number of texts on this which provide a clear insight into its basic concepts. In *Sūrya Siddhānta* (the period being even before the Christian era),[2] for example, the motion of planets including the solar and lunar eclipses, had been calculated to an extent which is more or less in agreement with the modern astronomical calculations. Nevertheless, a keen scientific observation of the older approaches

reveals a basic and subtle distinction between the two, the nature of which will perhaps manifest itself by the following discussions.

Physics and philosophy are complementary to each other. Physics seeks to investigate and reveal the secrets of Nature in a systematic and logical manner. But they remain mazes, until such a time as philosophy and allied literature bring them into focus. Philosophy, in general, proposes a hypothesis to solve the mazes in abstract manner. As laboratory verifications are difficult, same sets of mazes may have wide number of hypotheses as the solutions, which, in turn, give rise to a number of philosophical schools. This is what has happened in this world. A dawn might come when all these philosophical hypotheses are subjected to test by laboratory experiments on the basis of the discovery of a methodology to handle even the metaphysical quantities as simply as other physical quantities. In this way, to perceive physics in its totality, a philosophical view is necessary, and for perfection in philosophy, a scientific view is essential. It is very interesting to observe that the fundamental principles established by scientist of the day had already been stated no less profoundly by the scholars of ancient India. If a study of their doctrines is made with the help of contemporary mathematics and modern scientific instruments, new vistas may very well open up for scientific researches.

2.2 The Need of Mathematics in Physics

For the study of physics, knowledge of mathematics is must; it is indispensible. In other words, mathematics is the language or medium which can express the principles of physics with exactness and precision. Thus, mathematics possesses the power to express the elements of physics. In physics when a law regarding any physical quantity (matter, energy, space and time) is to be established, its properties related with other physical quantities need to be translated into a meaningful mathematical equation. These are experimentally verified. The conclusions drawn through experiments establish the principle, or law vis-a-vis physical quantity under reference.

When the principles or the laws with reference to a natural phenomenon established through perception, inference, analogue and

authoritative expressions or axioms are not directly verified through any sense organ or scientific instrument, its effect is brought under limits of perception of the sense organs or that of the instruments only with the help of mathematics. So in order to keep the findings of physics under control, it is important to know mathematics, and use it effectively to make comparisons and arrive at conclusions.

Mathematics is the science of numbers and abstractness in which groups are formed with the help of logic and the laws are framed for their addition, subtraction, etc. on the firm grounds of logic (*Nyāya* school of Indian philosophy); or, one can say, mathematics is an 'art' of logic. Thus, whenever *Nyāya* is required to establish or define a physical quantity (the abstract), mathematics provides the answer. That is why, it is important to discuss the logical analysis of mathematics, which is done in Chapter 5.

2.3 Definition of Physics

Physics[3] is the branch of science which sets as its object the ability to predict behaviour of natural phenomena with the help of a system of laws derived from observations and experiences. Physics is a quantitative science. There are two main branches of physics: (a) the experimental, and (b) the theoretical. The experimental branch is the science of observation and experiment gives accurate knowledge of the actual behaviour of natural systems. The theoretical branch builds up a system of quantitative relations among measured quantities, and formulates these relations, with the help of mathematics, into physical laws.

Notes and references

1. Satya Prakash, *Founder of Sciences in Ancient India*, p. 302, 1965, The Research Institute of Ancient Scientific Studies, New Delhi.
2. Satya Prakash, *Founder of Sciences in Ancient India*, p. 542, 1965, The Research Institute of Ancient Scientific Studies, New Delhi.
3. *The World University Encyclopedia*, Vol.-9, 1965, Publishers Company, Inc, Washington.

3

Padārtha: The Physical Quantity

3.1 *Padārtha* and its Counterpart

Man has always been surrounded by different kinds of natural objects. Throughout evolution, he has been observing and subsequently studying the changes instinctively, the changes which take place in the properties and mode of behaviour, etc. and become the cause for the development of natural sciences. It is perhaps due to this instinct that Maharṣi Kaṇāda propounded his *Vaiśeṣika Darśana.* In this *Darśana*, physical quantities[1] (abstracts) have been enumerated as *Dravya, Guṇa, Karma, Samānya, Viśeṣa* and *Samavāya.* Here, *Dravya*[2] includes solid, liquid, energy, gas, plasma, space, (strictly the length vector), time, soul and mind.

Vaiśeṣika Darśana claims that the first four are the causes for creation (*amīṣvādyānāṁ caturṇāṁ drvyāṇāṁ dravyārambhakatwam*). Plasma, space (or vector) and time[3] are eternal and all pervading. Physics has not yet said anything about soul and mind. According to *Vaiśeṣika*, *Ātma* or soul is the cause for sense and feeling, as the observer and mind or *Mana* is its instrument of gaining experience.

Vaiśeṣika Darśana has discussed mind and soul, though they are outside the realm of the physical quantities of the materialistic world, yet justified, since they are elements, very much required for cognition, observation and experience. In modern physics, *Dravyas*, like solid, liquid, etc., are discussed. In this book, *Pṛthvī* to *dik*', the first seven *Dravyas*, will be discussed, and a comparison will be made with their counterparts in physics.

3.2 *Vaiśeṣika* as Material Science[4]

According to physics, '*Padārtha*' may be taken as equivalent to a 'physical quantity'. However, according to *Vaiśeṣika*,' *Padārtha*' should include quantities related to basic matter (*bhūta*) and metaphysical matter (*Ātmā* and *Mana*), where basic matter (*bhūta*) is perceivable directly by physical sensory organs. Let the definition of physical quantity be restricted to basic matter, specific knowledge pertaining to it, or both. Further, basic matter itself is defined by identity, conjunctive relation of identity and cognition of cognizables even in a totally different relation with sensory organs. Specific knowledge will mean its inheritor, its conjunction to non-concomitant cause and its relation to other than its inheritor. Therefore, solid, liquid, energy, gas and plasma are 'basic matters,' or the matters in different states as they are perceivable through the sense organs like nose, tongue, eyes, skin and ear which establish the identity of relation with basic matters; space and time bear conjunctive relations with them. Property, motion, set, partlessness and concomitance have cognitive relation with basic matter. If soul and mind, which have conjunctive relation with non-concomitant cause, say the basic matter, they are either included as physical quantities or labelled separately as metaphysical quantities, the *Vaiśeṣika* philosophy regarding physical quantities will not be affected.

The physical quantities (abstract) of Kaṇāda are categorized in six classes or six fundamental abstract quantities[5], viz., (i) *Dravya* (the basic physical quantity), (ii) *Guṇa* (the property), (iii) *Karma* (motion), (iv) *Sāmānya* (set), (v) *Viśeṣa* (partlessness) and (vi) *Samavāya* (concomitance).

3.3 The Six *Padārthas* of *Vaiśeṣika*

Short definitions[5] of the six *Padārthas* of *Vaiśeṣika* are as follows:

(i) Basic physical quantity: Properties which are inherent.

(ii) Property: It does not have another property and is not an independent cause of conjunction and disjunction.

(iii) Motion: It is dependent on basic physical quantity but it does not possess property and is independent of conjunctions and disjunctions.

(iv) Set: The cause of assimilative cognition.
(v) Partlessness: The cause of ultimate differentiative cognition.
(vi) Concomitance: Non-conjunctive existence between inheritor and the inherited.

In *Vaiśeṣika Darśana,* the following sub-categories are enumerated:

(i) *Dravya* (Basic physical quantity)[6]:
1. Solid 2. Liquid 3. Energy 4. Gas 5. Plasma 6. Space or length vector 7. Time 8. Soul or organism 9. Mind or attention

(ii) *Guṇa* (property)[7]:
1. Colour (रूप) 2. Taste (रस) 3. Smell (गन्ध) 4. Temperature (स्पर्श) 5. Number (संख्या) 6. Unit (परिणाम) 7. Separateness (पृथक्त्व) 8. Conjunction (संयोग) 9. Disconjunction (विभाग) 10. Priority largeness (परत्व) 11. Posteriority smallness (अपरत्व) 12. Gravity (गुरुत्व) 13. Cohesion (द्रवत्व) 14. Adhesion (स्नेह) 15. Wave aspect (शब्द) 16. Intellect (बुद्धि) 17. Pleasure (सुख) 18. Pain (दुःख) 19. Desire (इच्छा) 20. Aversion, Malice (द्वेष) 21. Volition (प्रयत्न) 22. Cosmic order (धर्म) 23. Cosmic degeneracy or entropy (अधर्म) 24. Force (mechanical, elastic and emotional) (वेग).

(iii) *Karma*: (motion)[8]
1. Motion against gravity 2. Motion along gravity 3. Motion causing shear stress 4. Motion causing tensil stress 5. Linear motion.

(iv) *Sāmānya* (set)[9]
1. Universal set
2. Element

(v) *Viśeṣa* (partlessness)[10]
1. Quantum (finite)
2. Continuum (infinite)

(vi) *Samavāya* (concomitance)[11]

Mathematical Relation of Dependent Functions

Chapter 17 is devoted to explain the logical quantities 'set' to 'concomitance'. It is also shown in the chapter that the mathematical expression (equation) is a simultaneous expression, both qualitatively

and quantitatively, of all these logical quantities. Moreover, these quantities form the basis for the classical as well as modern mathematics.

Using the *Padārtha*[12] of *Nyāya* school of Indian philosophy, *Dravya* of *Vaiśeṣika* can be studied as parallel to physics.

As the *Nyāya* expresses the doctrines or principles in a deep intricate language, it is possible to express more precisely the well known physical principles by defining them in algebraical terms. When the various principles of *Vaiśeṣika Darśana* following their arrangement in accordance with that of *Praśastapāda Bhāṣya* are transcribed into proper mathematical expressions and are analysed and examined along with the use of the modern scientific instruments, wherever necessary, it will result in the scientific study of *Vaiśeṣika*. Such a study will no doubt be at par with physics. Moreover, the inclusion of soul or organism and mind in this study may further widen the scope of physics.

We are now in a position to undertake a critical study of *Dravya*, based on comparison with the corresponding physical quantities.

Notes and References

1. See Chapter 1, Notes and References 3
2. *Pṛthivivyāpastejo vāyuākāśaṁ kālo digātmā mana iti dravyāṇi* (*पृथिव्यापस्तेजो वायुराकाशं कालो दिगात्मा मन इति द्रव्याणि*), V.S. 1-2-5
3. *Dikkālāvakāśādibhyaḥ (दिक्कालावकाशादिभ्यः)*, S. S, 2-10
   Nityou you dikkālou tāvākāśaprakṛtibhūtou prakṛte guṇou viśeṣāveva. Ato dikkālayorvibhutvotpattiḥ. You tu khaṇḍadikkālou tou tatra upādhisaṁyogādākāśādutpadyete ityarthaḥ. Adiśabdenoupādhigrahaṇāditi.
   (*नित्यौ यौ दिक्कालौ तावाकाशप्रकृतिभूतौ प्रकृते गुणौ विशेषावेव। अतो दिक्कालयोर्विभुत्वोत्पत्तिः। यौ तु खंडदिक्कालौ तौ तत्र उपाधिसंयोगादाकाशादुत्पद्येते इत्यर्थः। आदिशब्देनोपाधिग्रहणादिति*)
4. See V.G.V., p. 9
5. *(i) Dravyaṁ: Guṇāśrayo dravyaṁ* (*द्रव्यम्: गुणाश्रयो द्रव्यम्।*)
   (ii) Guṇaḥ: sāmānyavān guṇaḥ saṁyogavibhāgayoranapekṣo na Kāraṇaṁ Guṇaḥ (*गुणः सामान्यवान् गुणः संयोगविभागयोरनपेक्षो न कारणं गुणः।*)
   (iii) Karma: Ekadravyamaguṇaṁ saṁyogavibhāgayoranpekṣakāraṇam karma. (*कर्मः एकद्रव्यमगुणम् संयोगविभागयोरनपेभकारणम् कर्म।*)

(iv) Sāmānyaṁ : Anuvṛttipratyayakāraṇaṁ sāmānyaṁ (सामान्यम्: अनुवृत्तिप्रत्ययकारणम् सामान्यम्।)

(v) Viśeṣaḥ: Atyantavyāvṛttibuddhiheturviśeṣaḥ. (विशेषः- अत्यन्तव्यावृत्तिबुद्धि हेतुर्विशेषः)

(vi) Samavāyāḥ: Ayutasiddhāyogāśrayāśrayibhāvaḥ samavāyaḥ (समवायः अयुतसिद्धायोगाश्रयाश्रयिभावः समवायः।) See N.K.T., *Uddeśya prakaraṇam (उद्देश्यप्रकरणम्)*

6. See Notes and References 2 of this chapter.

7. *Guṇāḥ (गुणाः) : 1. rūpaṁ (रूपम्) 2. rasaḥ (रसः) 3. gandhaḥ (गन्धः) 4. sparśaḥ (स्पर्शः) 5. saṅkhyā (संख्या) 6. parimāṇaṁ (परिमाणम्) 7. pṛthaktvaṁ (पृथक्त्वम्) 8. saṁyogaḥ (संयोगः) 9. vibhāgaḥ (विभागः) 10. paratvaṁ (परत्वम्) 11. aparatvaṁ (अपरत्वम्) 12. gurutvaṁ (गुरुत्वम्) 13. dravatvaṁ (द्रवत्वम्) 14. snehaḥ (स्नेहः) 15. śabdaḥ (शब्दः) 16. buddhiḥ (बुद्धिः) 17. sukhaṁ (सुखम्) 18. duḥkhaṁ (दुःखम्) 19. icchā (इच्छा) 20. dveśāḥ (द्वेषः) 21. prayatnaḥ (प्रयत्नः) 22. dharmaḥ (धर्मः) 23. adharmaḥ (अधर्मः) 24. saṁskārāḥ (संस्काराः)।*

8. *Karmāṇi (कर्माणि) : 1. Utkṣepaṇaṁ (उत्क्षेपणम्) 2. apakṣepaṇam (अपक्षेपणम्) 3. ākuñcanaṁ (आकुञ्चनम्) 4. prasāraṇaṁ (प्रसारणम्) 5. gamanam (गमनम्)।*

9. *Sāmānyaḥ (सामान्यः) : 1. paraṁ (परम्) 2. aparaṁ (अपरम्)।*

10. *Viśeṣaḥ (विशेषः) : 1. paramāṇu (परमाणु) 2. vibhu (विभु)।*

11. *Samavāya: Ayutasiddhānāmādhāryādhārabhūtānāṁ yaḥ sambandhaḥ (समवायः अयुतसिद्धानामाधार्याधारभूतानां यः संबन्धः)* P.B., pp10-14

12. See N.S., 1-1-1, *Pramāṇa-prameya-saṁśaya-prayojana-dṛṣṭānta-sidhānta-avayava-tarka-nirṇaya-vāda-jalpa-vitaṇḍā-hetvābhāsa-chala-jāti-nigrahasthānānāṁ tattvajñanānniḥśreyasādhigamaḥ (प्रमाण-प्रमेय-संशय-प्रयोजन-दृष्टान्त-सिद्धान्त-अवयव-तर्क-निर्णय-वाद-जल्प-वितण्डा -हेत्वाभास-छल-जाति-निग्रहस्थानानां तत्त्वज्ञानान्निः श्रेयसाधिगमः)।*

4

Dravyam: The Basic Physical Quantity

4.1 *Pṛthvī, Apa, Vāyu* (Solid, Liquid and Gas)

Modern physics does not include soul and mind in quantities related to basic matter. We will, therefore, consider only the first seven of the *Dravyas* mentioned in *Vaiśeṣika.*

By definition, *Dravyas* are said to be those quantities in which properties are inherent. To begin with, we are considering the first five basic physical quantities from the point of view of modern thought.

Their specific properties are smell, taste, colour, temperature and sound (wave-acoustical) perceived through the respective sense organs; viz. nose, tongue, eyes, skin and ears. In order to distinguish solid, liquid and gas in physics from those in *Vaiśeṣika,* we will call them perfect solid, perfect liquid and perfect gas. Now the solid, liquid, energy and gas of *Vaiśeṣika,* possess the properties[1]: smell, taste, colour and temperature in an order where each successive form will have one less property than its predecessor, i.e. the perfect solid will have all the four, the perfect liquid three (taste, colour and temperature), energy two (colour and temperature), and perfect gas only one (temperature). The fifth *Dravya,* namely *ākāśa* (plasma state) is devoid of these four properties, namely smell, colour, taste and temperature. Wave aspect is the only property of *ākāśa.* Here, one should note that the term *sparśa*[2] of *Vaiśeṣika* has been replaced by temperature, as temperature is the physical quantity which gives the sense of hot and cold, etc. when hardness and softness have to be expressed in *Vaiśeṣika.* The term *sparśa* must be prefixed with *viśeṣa,* that is, these are termed

as *'viśeṣa sparśa'*. Thus, *sparśa* is temperature. In physics we have well known gas and thermodynamic scales of temperature. According to *Vaiśeṣika,* these measures are of specific dimension, because one property cannot be a part of the other. In perfect solids[3] the change into liquid occurs due to the conjunction of energy which is explained by the hypothesis of a temporal change.

This statement implies that the liquid state is incorporated in the solid due to the presence of fluid (kinetic) property in energy (heat). If it is not so, it is feared that the conjunction with the perfect gas will also be the cause of the natural liquid state. The property of smell lies in solid, and it may be felt both in liquid and gas due to the presence of the finer parts of the perfect solid. According to *Vaiśeṣika,* liquids and gases are odourless by nature.

Here we may discuss the above hypothesis on the ground that in the several texts of *Vaiśeṣika* there is no mention whether the knowledge of the method of production of gases other than the atmospheric gas was taken into account. It was known in ancient India that the water available in nature decomposes into two gases[4] viz., *prāṇavāyu* (oxygen gas) and *udāna vāyu* (hydrogen gas). A number of gases with odour have been mentioned in ancient text of *Āyurveda. Vāyu* and its synonym are found to have been used in different ancient texts, but not always in the sense of gases, which creates a lot of confusion.

In order to perceive the odour of any substance one has to inhale, the surrounding air that contains a substance and the analysis of air gives a number of gases. There is odour in some gases while some are odourless. When the molecules of a gas with odour come in contact with the sensory organ of inhalation, sense of smell is perceived. In fact, the odoriferous molecules mixed with the air molecules give a mixture of odoriferous gases.

The liquid (universally 'water' being the representative of the liquid state) also undergoes transformations. The water vapour rising from the ocean, ponds, etc. reaches the heights where low temperature and pressure cause it to condense as water drops and freeze into ice crystals to form clouds.

Thus, we conclude that solid, liquid and gas are different states of the same matter. No doubt, this inference is drawn from the universally available substance, water. Theoretically, as *Vaiśeṣika* assumes, we may consider three different states as states of perfect solid, perfect liquid and perfect gas. Actually, the same matter may appear in different states, all being temporal *(naimittika)*, this conclusion may be proved with the help of a small experiment. If the weight of a substance in any one of the said forms is determined and then it undergoes a transformation from the first state to any other state with care, no change in weight is detected by the balance; i.e. the law of conservation of matter is obeyed.

Philosophically, we may conclude that the *Vaiśeṣika* considers the ideal (perfect) states, which, when approximated with necessary considerations, begin to reflect the real states of matter. These ideas compare very favourably with the modern view of perfect and real gases.

4.2 *Aṇu, Dvyaṇuka* and *Trasareṇu* (Atom, Molecule and Smallest Colloidal Particle)

According to *Vaiśeṣika* individual atom *(aṇu)* does not possess any property, but as it combines with another atom, a diatomic molecule *(dvyaṇuka)* is formed, in turn, combines with other three similar molecules to produce a trimolecule *(trasareṇu)*; only then the properties are perceived.[5] Such a molecule, the constituents of which are three diatomic molecules forms the smallest unit known as *trasareṇu* (colloidal particle). These *trasareṇus* further combine to give the structure of gross bodies and their properties become suitable for direct perception.

4.3 *Pīlupākavāda* (Dalton's Theory of Chemical Reaction)[6]

In *pākakriyā*, that is, when change in properties is observed, properties cannot be restored by the general method. The changes due to *pākakriyā* are known as chemical changes in modern science. According to *Vaiśeṣika*, the physical properties like smell, taste and colour do not change up to diatomic molecules, but in the new arrangements of atoms of the new combinations which are formed by chemical reactions *(pākakriyā)*, in which the structure of the gross body breaks up into atoms, which re-establish themselves into a new arrangement. The molecules formed due to the chemical change, i.e. the chemical products

(pākaprabhava), shed the preceding properties and gain new properties. For *pākakriyā*, the conjunction of *teja* (energy) with matter is necessary. In a chemical process of *Vaiśeṣikas*, these molecules along with similar molecules, after combination, form a gross body having new properties. On the basis of the number of fundamentally different types of atoms *(Pañcīkṛta)*, i.e. the elements, the formation of different substances, not being the subject of this book, is omitted for the time being.

The *pīlūpāka* process can well be compared with Dalton's theory which has been already modified by Avogadro's hypothesis. It states that:

(i) Substances (elements and compounds) consist of molecules, i.e. ultimate particles capable of separate existence and the molecules are composed of indivisible particles called atoms.

(ii) Molecules of particular substances are similar to one another and possess the same properties and the same mass; but molecules of one substance are altogether different from the molecules of another substance.

(iii) Molecules of an element consist of atoms which are all alike, while molecules of a compound consist of dissimilar atoms.

(iv) When chemical combination takes place between two or more substances, the molecules of each substance are first disintegrated into atoms and then the atoms combine together to produce new molecules of a new substance.

4.4 Tyndall Effect in *Vaiśeṣika* and the Size of the Atom

Vaiśeṣika defines the size of an atom objectively. As an atom itself does not have any property, it cannot be perceived; the smallest particle that can be seen can only be a *trasareṇu*, and only then the properties (smell, taste, colour etc.) are perceived. Thus, the sixtieth part of *trasareṇu* will give the *kriyākṣetra* (range of action) of *paramāṇu* (atom). There is a verse[7] that puts the size of the atom objectively. The sixtieth part of the smallest dust particle *(rajaḥ)* seen in sunbeam is an atom. Now, for the students of modern science this may be compared with the *Tyndall effect*.

According to the Tyndall effect, a beam of light entering a dark room lights up the dust particles (colloidal particles) which are

seen floating in the air. Similarly, when a strong beam of light is concentrated on a colloidal solution, the path of the beam is illuminated by a bluish light and becomes visible when observed from the side.

Tyndall effect shows that the size of colloidal particles range from 0.2×10^{-4} cm to 1×10^{-7} cm. The one sixtieth part of the smallest dust particle will be 1×10^{-8} cm this proves that the size of the atom computed on the basis of *Vaiśeṣika* is of the same order of magnitude as that of an atom (1×10^{-8} cm) in physics. This also proves that the range of action of the atoms *(paramāṇu)* of *Vaiśeṣika* being the properties of chemical changes as well as the order of their size are the same as that of Bohr's atom.

4.5 *Teja* (Energy)

The observation, that chemical changes leave the quantity of matter unchanged strongly suggests that chemical change is a process of rearranging component parts.

The study of nuclear physics[8] has brought us into contact with the process in which mass releases an enormous amount of energy. As a result, the prediction of Einstein that radiant energy is mass, has been clearly verified. We know the fascinating process (on the atomic scale) in which 100% of the mass changes from particles of matter into radiation. And unless we trap the radiation, it will escape detection. But only in the nuclear laboratories, and in the natural nuclear engines in the centres of stars, do changes go on in which mass is noticeably converted into radiation. Except in nuclear reactions, we always ignore the minute changes in the mass. This means that the observed conservation of mass is normally equivalent to conservation of quantity of matter. In chemical changes the quantity of matter stays essentially the same.

4.6 *Ākāśa* (Plasma)

Ākāśa, the Sanskrit word, means a physical quantity which glows all around[9]. *Ākāśa* can be interpreted as the fourth state of matter, namely plasma. It is also obvious that this state of matter is spread all over the universe, including our planet.

In physics, plasma[10] is a mixture of ionized atoms (ions) and free electrons, with a sprinkling of whole atoms, and sometimes

even molecules of gas. While it is known that all gases, including the air we breathe, contain some ionized atoms and free electrons, the properties of plasma differ strikingly from those of gases. In plasma, the atoms are in an excited state, a continuous collision of electrons in the course of their random motions, is responsible for the glow of plasma. Plasma is an excellent conductor of electricity. The purity of plasma depends upon the degree of ionization. The upper temperature limit of chemical reactions is of the order of 6,000-8,000 degrees K. Beyond this limit, the 'true' state of plasma sets in.

Thus, the transformation from plasma to solid may be viewed as follows: true plasma is a completely ionized state of matter. It transforms into a gas of atoms of varying excited states, radiating enormous amounts of energy. The excited state of matter then goes over into molecular condition, dissipating its entire heat content (excitation energy), and becomes a gas similar to the gases of earth's atmosphere (i.e. behaving like a perfect gas). Matter is now in an electrically neutral perfect gas condition. At this state, matter has work energy which is subject to pressure and temperature variations, whereby it transforms into liquid state losing the heat content. The liquid then loses comparatively smaller heat content till it reaches a stage where it becomes rigid and cannot move on itself. Obviously this gives the series of transformations as plasma, gas, radiation (energy), liquid and then solid. This series is in accordance with the *Taittirīyopaniśad.*[11] A similar description of these transformations is given in *Vaiśeṣika*[12].

Thus, we conclude that the *Bhūta* (matter) of *Vaiśeṣika* of any state may transform into different states under suitable conditions, and these are perceivable states. The situation is consistent with that in modern physics. The term of *mahābhūta* of *Vaiśeṣika* means the respective perfect states of matter which are ideal states.

4.7 *Bhūta, Dik, Kāla* (The Fundamental Physical Quantities: Mass, Length and Time)

The sixth *dravya,* space *(dik)* and the seventh, time *(kāla)* possess a continuum and conjunctive relation with the matter of any state

(bhūta). Thus, *bhūta, dik* and *kāla* become the fundamental physical quantities, analogous to those of modern physics. As physics is the science of measurements, they are mass, length and time. Here mass and time are scalars while length is a vector.

4.8 A Tabular Comparision of *Vaiśeṣika 'Dravya'* and Physical Quantities

The essence of the above discussion may be tabulated as follows:

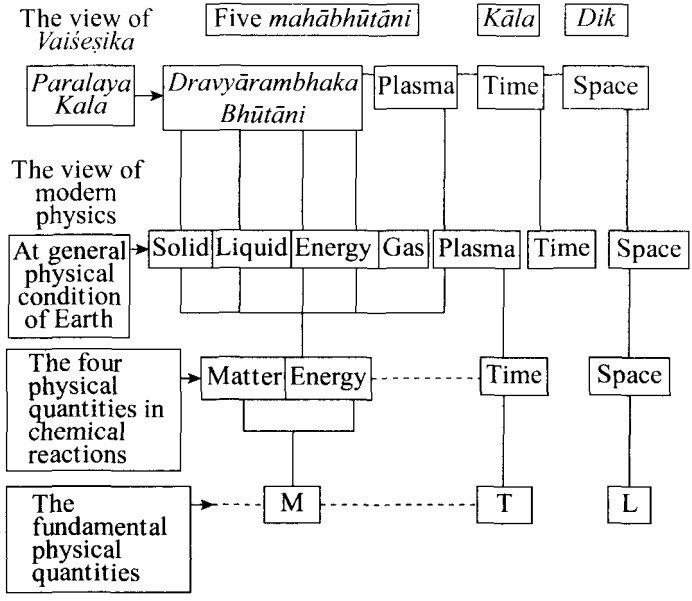


Table 1: Comparison of physical quantities of *Vaiśeṣika* with those of modern physics.

Notes and References

1. See V.S., 2-1-1 to 4

   Rūparasagandhasparśavatī prthivī. Rūparasasparśavatyāpo dravāḥ snigdhāh. Sparśavān vāyuh. Ta ākāśe na vidyante
   (रूपरसगन्धस्पर्शवती पृथिवी। रूपरसस्पर्शवत्य आपो द्रवाः स्निग्धाः। स्पर्शवान् वायुः। त आकाशे न विद्यन्ते)।

2. *Sparśastrividhaḥ śītoṣṇānuṣṇāśita iti bhedāt kāṭhinyādistu viśeṣasparśaḥ (स्पर्शस्त्रिविधः शीतोष्णानुष्ण शीत इति भेदात् काठिन्यादिस्तु विशेषस्पर्शः)* - *Tarka Saṇgraha.*

3. See V.S. 2-1-7
Trapusīsalohara jatasuvarnānām agnisaṁyogāt dravatvamadbhiḥ sāmānyaṁ (त्रपुसीसलोहरजतसुवर्णानाम् अग्निसंयोगात् द्रवत्वमद्भिः सामान्यम्)।

4. See page 136, P.S.S.S.
Śilpaśāstraṁ (शिल्पशास्त्रम्) (technology) as described in *Agasti Saṁhitā (अगस्तिसंहिता),* contains the details of flying car *(yāna) (यान)*.The description is as follows: After laying down the cleaned copper plates (*suśobhitaṁ tāmrapatraṁ*) *(सुशोभितं ताम्रपत्रं)* in an earthen vessel (*mṛṇmaye pātre*) *(मृण्मये पात्रे),* the layers of coal powder (*śikhigrīveṇa*) *(शिखिग्रीवेण),* moistened saw-dust *(ādrābhiḥ kāsṭhapāṁsubhiḥ) (आद्राभिः काष्ठपांसुभिः),* zinc *(dastā) (दस्ता),* and a soil of some kind *(loṣṭha) (लोष्टः)* are arranged over this in succession and then it is covered by mercury *(pāradaḥ) (पारदः)*. This gives rise to two powers *(tejou) (तेजौ)* known as positive and negative electricities *(maitrāvaruṇa) (मैत्रावरुण)*/ [The description is similar to that of first battery or cell for electric current by Volta in 1800 A.D.]. These powers decompose *(bhaṅgosti) (भंगोस्ति)* water *(jala) (जल)* into oxygen gas *(prānavāyu) (प्राणवायु)* [Michael Faraday gave laws of electrolysis in 1830.] By the action of such one hundred cells (*kumbhānāṁ*) *(कुंभानाम्)* the lightness of the produced hydrogen gas (*udānaḥ*) *(उदानः),* filled in an air tight balloon (*vāyu-bandhaka vastreṇa*) *(वायु-बन्धकवस्त्रेण)* fitted with a car (*yāna*) *(यान)* slung from netting, causes the car (*yāna*) *(यान)* to fly in the sky. [M. Charles, professor of Physics in Paris used hydrogen gas in the balloon in 1800-1804 A.D.].

Saṁsthāpya mṛṇmaye pātre tāmrapatraṁ suśobhitaṁ.
Chādayecchikhigrīveṇa cārdrābhiḥ kāsṭhapāṁsubhiḥ.
(संस्थाप्य मृण्मये पात्रे ताम्रपत्रं सुशोभितम्)।
(छादयेच्छिखिग्रीवेण चार्द्राभिः काष्ठपांसुभिः)।

Dastā loṣṭho nidhiatavyaḥ pāradāchhāditastataḥ.
Samyogājjāyate tejo maitrāvarunasaṁjñitam
(दस्ता लोष्ठो निधातव्यः पारदाच्छादितस्ततः)।
(संयोगाज्जायते तेजो मैत्रावरुणसंज्ञितम्)।

Anena jalabhaṅgosti prāṇodānṣu vāyuṣu
Evaṁ śatānāṁ kumbhānāṁ samyogaḥ kāryakṛt smṛtaḥ
(अनेन जलभंगोस्ति प्राणोदानेषु वायुषु)।
(एवं शतानां कुंभानां संयोगः कार्यकृत् स्मृतः)।

Vāyubandhakavastreṇa nibaddho yānamastake
Udānaḥ svalaghutvena vibhartyākāśayānakam
(वायुबन्धकवस्त्रेण निबद्धो यानमस्तके)।
(उदानः स्वलघुत्वेन विभर्त्याकाशयानकम्)।

5. See P.B., pp. 130-131
Paramamahattvaṁ anityaṁ tryaṇukādeva. (परममहत्त्वम् अनित्यं त्र्यणुकादेव।)
Tatreśvara-buddhimapekṣyotpannā paramāṇudvyaṇukeṣu bahutva saṅkhyā tairārabdhe kāryadravye tryaṇukādilakṣaṇe rūpādyutpatti samakālaṁ mahattvaṁ dīrghaṁ ca karoti
(तत्रेश्वर-बुद्धिमपेक्ष्योत्पन्ना परमाणुद्व्यणुकेषु बहुत्वसंख्या तैरारब्धे कार्यद्रव्ये त्र्यणुकादिलक्षणे रूपाद्युत्पत्तिसमकालं महत्त्वं दीर्घत्वं च करोति)।

6. See P.B., ppl06-107
Pārthivaparamāṇurūpādīnāṁ pākajotpattividhānam.
Ghaṭāderāmadravyasyāgninā sambaddhasyāgnyabhighātānn-odanādvā tadāraṁbhakeṣvaṇuṣu karmāṇyutpadyante tebhyo vibhāgaḥ vibhagebhyaḥsaṁyogavināśāḥ saṁyogavināśebhyaśca kāryadravyaṁ vinaśyati. Tasmin vinaṣṭe svatantreṣu paramāṇuṣv-agnisaṁyogādouṣṇyāpeksācchyāmādinām vināsaḥ punaranyasm-ādagnisaṁyogādousnyāpekṣat pākajā jāyante. Tadanantaraṁ bhoginām adṛṣṭāpeksādātmāṇusaṁyogātpannapākajeṣvaṇus u karmotpattou teṣāṁ parasparasaṁyogād dvyaṇukādikrameṇa kāryadravyamutpadyate.
(पार्थिवपरमाणुरूपादीनां पाकजोत्पत्तिविधानम्। घटादेरामद्रव्यस्याग्निना सम्बद्ध स्याग्न्यभिघातान्नोदनाद्वा तदारंभकेष्वणुषु कर्माण्युत्पद्यन्ते तेभ्यो विभागः विभागेभ्यः संयोगविनाशाः संयोगविनाशेभ्यश्च कार्यद्रव्यं विनश्यति। तस्मिन् विनष्टे स्वतन्त्रेषु परमाणुष्वग्निसंयोगादौष्ण्यापेक्षाच्छ्यामादिनां विनाशः पुनरन्यस्मादग्निसंयोगादौष्ण्यापेक्षात् पाकजा जायन्ते। तदनन्तरं भोगिनाम् अदृष्टापेक्षादात्माणुसंयोगोत्पन्नपाकजेष्वणुषु कर्मोत्पत्तौ तेषां परस्परसंयोगाद् द्व्यणुकादिक्रमेण कार्यद्रव्यमुत्पद्यते।
The size of atom = 8^{-7} *aṅguliparimānam* = 0.5 Å = 0.5 X 10^{-8} cm.

7. *Jālāntargate bhāno yat sūkṣmaṁ dṛṣyate rajaḥ.*
(जालान्तर्गते भानौ यत् सूक्ष्मं दृष्यते रजः)।
Tasya ṣaṣṭhitamo bhāgaḥ paramāṇuḥ prakīrtitaḥ.
(तस्य षष्टितमो भागो परमाणुः प्रकीर्तितः)।

8. See, *Physics, N. C. E. R. T.* p. 104

9. See *Amarakośa.*
Āsamantāt kāśate iti ākāśaḥ, "Kaśṛ dīptou" iti dhātoḥ
(आसमन्तात् काशते इति आकाशः "कशृ दीप्तौ" इति धातोः)

10. See *Matter and Man*, pp 41-45

11. See *T.U. Yajurāraṇyak, brahmavalli, dvitīya praśna, prathama anuvāka (यजुरारण्यके ब्रह्मवल्लि-द्वितीयप्रश्न-प्रथमो अनुवाकः),* T.U.
Tasmādvā etasmādātmanaḥ ākāśassaṁbhutaḥ / Akāśādvāyuḥ/ Vāyorgniḥ / āgnerāpaḥ / Adbhyaḥ prthivī/ (तस्माद्वा एतस्मादात्मन आकाशस्संभूतः / आकाशाद्वायुः / वायोरग्निः / अग्नेरापः / अद्भ्यः पृथिवी।)

12. See P.B., pp 48-49
Tataḥ punaḥ prāṇānām bhogabhūtaye maheśvarasisṛkṣānantaraṁ sarvātmagatavṛttilabdhādṛṣṭāpekṣebhyastatsaṁyogebhyaḥ pavanparamāṇusu karmotpattou teṣāṁ parasparasaṁyogebhyo dvyaṇukādiprakrameṇa mahanvāyuḥ samutpanno nabhasi dodhūyamānastiṣṭhati. Tadanantaraṁ tasminneva vāyāvāpyebhyaḥ paramāṇubhyastenaiva krameṇa mahān salilanidhirutpannaḥ popluyamānastiṣṭhati Tadanantaraṁ tasminneva parthivebhyaḥ paramāṇubhyo mahāpṛthivī samhatāvatiṣṭhate. Tadanantaram tasminneva mahodadhou tejasebhyo(a)*ṇubhyo dvyaṇukādi-prakrameṇotpanno mahan tejorāśiḥ kenacidanabhibhūtatvāddaidī pyamānastiṣṭhati*
(ततः पुनः प्राणानां भोगभूतये महेश्वरसिसृक्षानन्तरं सर्वात्मगतवृत्तिलब्धादृष्टापेक्षेभ्यस्तत्संयोगेभ्यः पवन्परमाणुषु कर्मोत्पत्तौ तेषां परस्परसंयोगेभ्यो द्व्यणुकादिप्रक्रमेण महान्वायुः समुत्पन्नो नभसि दोधूयमानस्तिष्ठति। तदनन्तरं तस्मिन्नेव वाय्वाप्येभ्यः परमाणुभ्यस्तेनैव क्रमेण महान् सलिलनिधिरुत्पन्नः पोप्लुयमानस्तिष्ठति तदनन्तरं तस्मिन्नेव पार्थिवेभ्यः परमाणुभ्यो महापृथिवी संहतावतिष्ठते। तदनन्तरं तस्मिन्नेव महोदधौ तेजसेभ्यो अणुभ्यो द्व्यणुकादिप्रक्रमेणोत्पन्नो महान् तेजोराशिः केनचिदनभिभूतत्वाद्दैदीप्यमानस्तिष्ठति)।

5

Guṇāḥ: Properties of Fundamental Physical Quantities

5.1 Introduction

The first four *dravyāḥ* viz., solid, liquid, energy and gas are non-eternal quantities, while plasma, time and space (length vector) are eternal quantities. Thus, the first four quantities mentioned above are finite, while the others are in a sense, continuous quantities. This is the reason that the properties of *dravyāḥ* can be stated to be one of the three types[1] —finite, continuous and having both the characters.

The description of these properties is given in several texts devoted to *Vaiśeṣika*. In this discussion, except the properties like *buddhi* (cognition), *sukha* (pleasure), *dukkha* (pain), *icchā* (desire), *dveṣa* (aversion), *prayatna* (volition), *dharma* (cosmic order), *adharma* (cosmic degeneracy—entropy) and *bhāvanā saṁskāra* (emotional force), pertaining to *Ātmā* and *Mana* (soul and mind), the other remaining properties viz., *pārthakya* (separateness), *rūpa* (colour), *rasa* (taste), *gandha* (smell), *sparśa* (temperature), *saṇkhyā* (number), *parimāna* (unit), *saṁyoga* (conjunction), *vibhāga* (disconjunction), *paratva* (largeness), *aparatva* (smallness), *gurutva* (gravity), *dravatva* (fluidity-cohesion) *sneha* (adhesion), and *saṁskāra* (force, mechanical and elastic) are being considered. The properties are further divided into two classes viz., general *(sāmānya)* and specific *(viśeṣa)*[2]. The properties under general class include number, unit, conjunction, disconjunction, smallness, largeness, gravity, temporal fluidity (cohesion), and mechanical and

elastic forces. 'Specific' properties are enumerated as colour, smell, taste, temperature, adhesion, cohesion and the wave aspect. This classification is shown in a tabular form in Fig. 1.

Guṇāḥ Properties of Fundamental Physical Quantities

Prthvī (Solid)	*Ap* (Liquid)					
Gandha (Smell)	*Sneha* (adhesion)					
Gurutva (Gravity)	*Gurutva* (Gravity)					
Rasa (Taste)	*Rasa* (Taste)	*Teja* (Energy)				
Asamsiddhika (Temporal cohesion)	*Samsiddhika* (Local cohesion)	*Asamsiddhika* (Temporal cohesion)				
Rūpa (Colour)	*Rūpa* (Colour)	*Rūpa* (Colour)	*Vayu* (Gas)			
Spaŕsa (Temperature)	*Spaŕsa* (Temperature)	*Spaŕsa* (Temperature)	*Spaŕsa* (Temperature)			
Samskāra (Force)	*Samskāra* (Force)	*Samskāra* (Force)	*Samskāra* (Force)			
Aparatva (Smallness)	*Aparatva* (Smallness)	*Aparatva* (Smallness)	*Aparatva* (Smallness)	*Ākāśa* (Plasma)		
Paratva (Largeness)	*Paratva* (Largeness)	*Paratva* (Largeness)	*Paratva* (Largeness)	*Sabda* (Sound)	*Kalā* (Time)	*Dik* (Space)
Vibhāga (Disjunction)	*Vibhāga* (Disjunction)	*Vibhāga* (Disjunction)	*Vibhāga* (Disjunction)	*Vibhāga* (Disjunction)	*Vibhāga* (Disjunction)	*Vibhāga* (Disjunction)
Samyoga (Conjunction)	*Samyoga* (Conjunction)	*Samyoga* (Conjunction)	*Samyoga* (Conjunction)	*Samyoga* (Conjunction)	*Samyoga* (Conjunction)	*Samyoga* (Conjunction)
Pārthakya (Sepatateness)	*Pārthakya* (Sepatateness)	*Pārthakya* (Sepatateness)	*Pārthakya* (Sepatateness)	*Pārthakya* (Sepatateness)	*Pārthakya* (Sepatateness)	*Pārthakya* (Sepatateness)
Parimāna (Unit)	*Parimāna* (Unit)	*Parimāna* (Unit)	*Parimāna* (Unit)	*Parimāna* (Unit)	*Parimāna* (Unit)	*Parimāna* (Unit)
Sankhyā (Number)	*Sankhyā* (Number)	*Sankhyā* (Number)	*Sankhyā* (Number)	*Sankhyā* (Number)	*Sankhyā* (Number)	*Sankhyā* (Number)
Sāmānya Guna			*Viśeṣa Guna*			

Fig. 1: Representation of *Sāmānya* and *Viśeṣa Guṇāḥ*

5.2 *Sāmānya Guṇāḥ* (General Properties)

The list of *sāmānya guṇāḥ* (general properties) is shown in Fig.1. Number and unit are more important than other properties because it is on their basis that the precise measurement of the other properties is possible. For example, largeness and smallness are of two kinds, depending upon their reference to space or time. How far or close a body is, can be determined by the largeness or smallness of the distance from the point of reference; while priority or posteriority is determined by the largeness and smallness of time (interval) reckoned with reference to a standard clock. Thus, the knowledge of three dimensional space and time continuum along with proper unit and number can define the location of finite material quantities (see Chapter 11). The rest of general properties viz. conjunction and disconjunction, gravity, fluidity, mechanical and elastic forces have been studied in the Chapters 11, 14, 8, 12 and 13 respectively.

5.3 *Viśeṣa Guṇāḥ* (Specific Properties)

The properties of taste and smell have meagre importance in physics, while adhesion and cohesion will be discussed in Chapter 8, which is devoted to liquid state.

Though in this work we have focused mainly on the general properties, brief discussions over properties such as wave aspect, colour and temperature have also been given in Chapters 15 and 16 respectively, so that a better comparison between *Vaiśeṣika* and physics can be appreciated by the reader.

5.4 Measurements in Physics

In this chapter, we will discuss the measurement of the fundamental physical quantities. The three essential measurements are: length *(dik)*, mass *(pārthivamānam)*, and time *(kāla)*, which in turn will provide a way for the measurement of motion (Chapter 11).

5.5 *Dik Parimeyatva* (Measurement of Length)

Solid, liquid and gas posses **length** measurability. These solids, liquids or gases depending upon their state, occupy a volume in space, the volume being a quantity measured in terms of length and similarly, the

knowledge of exposed surface area may also be well understood through the knowledge about length, therefore for the sake of measurement, we must first define the units of length, area and volume.

The knowledge of *dik* (length vector) is important. According to *Vaiśeṣika*[3], by virtue of the length vector an observer perceives an object to be at a distance or close to him. Although this vector is eternal (any direction being infinite), it is in relation to a finite material body or a celestial object; variously labelled as Eastward, Westward, etc. Generally, the direction extending from an observer facing the sunrise is, East and that extending from the same observer facing the sunset is West. Similarly, if the person faces the North pole *(sumeru)*, the direction is North, while South is the direction just opposite to it.

It is important to stress that the knowledge of unit and number in a given direction is necessary for decisive determination of the farness or nearness of an object by a 'length vector.' Thus, for measurements, the distance between two fixed points must be taken as a unit[4]. Now, depending upon this unit, the distance between any two points is determined. The method adopted is called 'measurement'. The number[5] of times by which 'the unit length' repeats itself between two given points along with the fractional part of this unit, if any; defines the length between the given points. Thus, the length in a given direction is described by numbers and unit together. The laws of addition, subtraction, multiplication, division, square and square-root are well described in Sanskrit mathematics. This mathematics *(satkarma)* is based on logic *(Nyāya Darśana)* and may be used in place of literary description. Applying the laws and method of mathematics, the area and volume *(kṣetrafalānayanam* and *ghanafalānayanam)* related to the substance may be determined quantitatively, while literary descriptions provide only qualitative idea about them.

For every physical quantity, a unit of the same kind *(jāti:* for physical quantities the differentiation is made through 'dimension') is designed. The magnitude *(parimāṇam)* is taken as 'one' (or a unit). The length, breadth, depth, the distance between two points, etc. are the quantities of the same kind. The units which are in practice from ancient times are *aṇguli, hasta, daṇḍa, yojana*[6], etc.

For the measurements of area of curved surface, plane surface, etc. of the faces of a body, *varga-aṇguli, varga-hasta, varga- daṇḍa, varga-yojana,* etc. are the units. Similarly, the units for volume of the body are *ghana-aṇguli, ghana-hasta,* etc.

5.6 *Saṅkhyā* (Number)

The term used to measure the multiples or a fraction of unit is the 'number'. Even for the numbers[7] which are used in counting process, the different denominations like tens, hundreds, thousands, etc. may show respective kinds *(jāti)* of numbers. These kinds themselves define their units, e.g. when we say three thousands, here three is number and 'thousand' is like a unit.

For every substance, all the properties are not always directly measurable. For instance, the volume of a cylinder or cylindrical hole, interplanetory distances, the volume of Earth, the difference between the volumes of two bodies, etc. are not directly measured. So whenever, direct measurement is not possible, we depend upon methods of analogy resting upon the precise knowledge of the mathematical principles.

5.7 *Gaṇitam* (Mathematics)

Simple and easier methods are designed on the basis of mathematical inferences. The science of these methods, used for measuring a quantity or in counting, may be called mathematics. Mathematics is an 'art' of logic *(Nyāya śāstraṁ)* capable of expressing the principles of logic in mathematical language. Counting depends upon the principles of mathematics, and the value thus determined is closer to reality than to any imaginative method of logic.

In mathematics, numbers, line, area, volume, etc. and their similarities and differences are mainly discussed. The laws drawn in the form of the rules of addition, subtraction and other operations have been laid down. All these rules and operations have been first proved on the principles of logic and then accepted in mathematics.

Now, we will provide an evidence from *'Līlāvatī'*[8]. *Bhāskarācārya,* the author of *Līlāvatī,* has shown how the addition and subtraction

are based on the principles of logic. He gives the process in the verse saying that addition or subtraction are to be done in direct or reverse manner with consideration to their respective places.

In general, the numbers are handled from left to right, which is the direct manner, and handling in the opposite is the reverse manner. The numbers of first place can be added or subtracted from the number of that place and so on.

According to logic *(Nyāya),* the addition or subtraction is only possible between the quantities of the same kind (species or dimension)[10]; that is why, we have addition or subtraction of numbers belonging to equivalent places. Similarly, it is possible to show that the other operations (like multiplication, division, squaring, and finding the cube) and all other mathematical operations are established by logic, but their treatment is not necessary in the present discussion.

5.8 *Pārthivamānaṁ* (Measurement of Mass)

Falling of bodies[11], downward flow of the liquid[12], presence of smell[13], temporal changes of states of solid, liquid, etc.[14], the effects of pressure and impact[15], motion[16]—all these show a close relationship between the solid, liquid and gaseous states of *Vaiśeṣika.*

In physics, solids, liquids and gases have been studied which indicates that the difference between the states is due to intermolecular spaces. All the above said materials possess mass *(pārthiva parimāṇam).* The unit of *pārthiva parimāṇa* is *māṣa,* which is equivalent to the mass of water of one *ghana aṇguli* volume[17]. This can be determined with the aid of a balance.

5.9 *Kāla* (Time)

Time is that by which evolution is perceived. It is a quantity like *dik.* When it comes in conjunction with finite physical quantities, the changes in their properties and motion, etc. are recognised. In section 5.2, while discussing the largeness and smallness of time, we measured time with reference to a standard clock. Again, time needs a unit and number to define priority and posterity.

Vaiśeṣika has enumerated a number of units; for details it is suggested that the reader may refer to *Gaṇita-śāstram* (mathematics). In those days mathematics and astronomy were allied subjects.

Astronomy favours two different units of time viz., sidereal day and solar day. The sidereal day is of constant length and so would serve as a unit of time, but it is not a convenient unit, as we obviously need a unit closely related to the day measured by Sun. The solar day was further divided either in sixty parts or twenty four parts, known as '*ghaṭi*' and *'horā'* respectively.

Notes and References

1. See P.B., p.95
   Rūporasagandasparśaparatvāparatvagurutvadravatvasnehavegā mūrtaguṇāḥ. Buddhisukhaduḥkhecchādveṣaprayatnadharmādhar ma bhāvanāśabdā amūrtagunāḥ. Saṅkhyāparimāṇapṛthaktvasaṁyo gavibhāgaubhaya guṇāḥ
   (रूपरसगन्स्पर्शपरत्वापरत्वगुरुत्वद्रवत्वस्नेहवेगा मूर्तगुणाः। बुद्धिसुखदुःखेच्छाद्वेषप्रयत्नधर्माधर्म -भावनाशब्दा अमूर्तगुणाः। संख्यापरिमाणपृथक्त्वसंयोगविभागाः उभयगुणाः।)

2. See P.B., pp 95-96
   Rūparasagandhasparśasneha
   sāṁsidhikadravatvabuddhisukhaduḥkhecchādveṣaprayatna-
   dharmādharmabhāvanāśabda vaiśeṣikā guṇāḥ.
   Saṅkhyāparimāṇapṛthaktvasaṁyogavibhāgaparatvāparatvagurutva
   naimittikadravatvavegāḥ sāmānyaguṇāḥ
   (रूपरसगन्धस्पर्शस्नेहसांसिद्धिकद्रवत्वबुद्धिसुखदुःखेच्छाद्वेषप्रयत्नधर्माधर्मभावनाशब्दा
   वैशेषिका गुणाः।
   संख्यापरिमाणपृथक्त्वसंयोगविभागपरत्वापरत्वगुरुत्व नैमित्तिकद्रवत्ववेगाः सामान्यगुणाः।)

3. See B.P., verses 46-47
   Dūrāntikādidhīhetureka nityā digucyate
   Upādhibhedādekā(a)pi prācyādivyapadeśabhāk
   (दूरान्तिकादिधीहेतुरेका नित्या दिगुच्यते।
   उपाधिभेदादेकाऽपि प्राच्यादिव्यपदेशभाक्।।)

4. B.P., 109
   Parimāṇaṁbhavenmānavyavahārasya kāraṇam
   (परिमाणं भवेन्मानव्यवहारस्य कारणम्।)

5 B.P., 106

Gaṇanāvyavahāre tu hetuḥ saṁkhyābhidhīyate
(गणनाव्यवहारे तु हेतुः संख्याभिधीयते।)

6 See chapter 6.1.
96 *aṁguli* = 4 *hasta* = 1 *daṇḍa* = 1 metre
1 *yojana* = 8000 *daṇḍa* = 8000 metre

7. *Līlāvatī*, 2

8. *Kāryaḥ kramādutkramatotha vāṁkayogo*
yathāsthānakamantaraṁ vā —*Līlāvatī*
(कार्यः क्रमादुत्क्रमतोऽथ वांकयोगो यथास्थानमनन्तरं वा।)

9. *Aṁkānām vāmato gatiḥ–Līlāvatī (अंकानां वामतो गतिः- लीलावती)।*

10. See Chapter 17.1

11. V.S.,5-1-18
Samskārābhāve gurutvāt patanam (संस्काराभावे गुरुत्वात् पतनम्)।

12. V.S., 5-2-3
Apāṁ saṁyogābhāve gurutvāt patanam (अपां संयोगाभावे गुरुत्वात् पतनम्)।

13. V.S.2-2-1, 2
Kṣitāveva gandhaḥ. Ayamasyārthaḥ kevala evāyamasādhāraṇadharma iti. Śugandhiḥ salilaṁ sugandhiḥ samīran a iti pratyayād dravyāntarei(a)pi gandho(a)stīti cenna, pārthivadravyasamavāyena tadguṇopalabdheḥ. Dravyagranthe pṛthivī-nirūpaṇaṁ - Nyāyakandalī
(क्षितावेव गन्धः। अयमस्यार्थः केवल एवायमसाधारणधर्म इति। सुगन्धिः सलिलं सुगन्धिः समीरण इति प्रत्ययाद् द्रव्यान्तरेऽपि गन्धोऽस्तीति चेन्न, पार्थिवद्रव्यसमवायेन तद्गुणोपलब्धेः। (द्रव्यग्रन्थे पृथिवीनिरूपणं-न्यायकन्दली)।

14. See V.S. 2-2 - 6-7

15. V.S. 5-2-1
Nodanābhighātāt saṁyuktasaṁyogācca pṛthivyāṁ karma
(नोदनाभिघातात् संयुक्तसंयोगाच्च पृथिव्यां कर्म।)

16. V.S. 5-1-14
Tṛṇe karma vāyusaṁyogāt (तृणे कर्म वायुसंयोगात्)
V.S. 5-2-12
Apāṁ saṁyogādvibhāgācca stanyaitnoḥ (अपां संयोगाद्विभागाच्च स्तनयित्नोः।)
V.S. 5-2-4, etc.
Agnerūrdhvajvalanaṁ vāyostiryak pavanamaṇūnāṁ manasaścādyam karmādṛṣṭakāritaṁ
(अग्नेरूर्ध्वज्वलनं वायोस्तिर्यक् पवनमणूनां मनसश्चाद्यं कर्म्मादृष्टकारितम्)

17. See Chapter 7.1, 1 *māsa* = 1.130292 gms

6

Dikparimeyatvam: Length Measurement

6.1 Units and Derived Units of Length

The units and derived units of length as used by the ancient Indians are as follows:

8 *paramāṇu* = 1 *trasreṇu*
8 *trasareṇu* = 1 *reṇu*
8 *reṇu* = 1 *bālāgra*
8 *bālāgra* = 1 *likhya*
8 *likhya* = 1 *yuka*
8 *yuka* = 1 *yava*
8 *yava* = 1 *aṅguli*

21 *aṅguli* = 1 *ratni*
24 *aṅguli* = 1 *hasta*
4 *hasta* = 1 *daṇḍa*
2000 *daṇḍa* = 1 *krośa*
4 *krośa* = 1 *yojana*
96 *aṅguli* = 1 *daṇḍa*
8000 *daṇḍa* = 1 *yojana*[1]

The unit of length based on the modern decimal system is metre. It is the distance between the two marks of platin-iridium rod (literally *daṇḍa*) kept at 0^0C in Paris. This length was a millimicro (nano) part of longitude (then known) passing through Paris. Nowadays, the accurate determination of Earth's radius makes this length slightly shorter than it was considered to be. The multiples and subdivisions of metre are as follows:

10 millimetres = 1 centimetre
10 centimetres = 1 decimetre
10 decimetres = 1 metre
10 metres = 1 decametre

10 decametres = 1 hectometre

10 hectometres = 1 kilometre

It will be interesting if we make a comparison between metre and *daṇḍa*. According to *Sūrya Siddhānta*[2], the radius of Earth is 800 *yojana*. The radius of Earth in decimal system is 6.37 x 10^8 centimetres.

Thus,

1 *Yojan* = 8000 metre

= 8000 *daṇḍa* (from table in Chapter 6.1),

Therefore, 1 *daṇḍa* = 1 metre.

As one *aṅguli* is ninty-sixth part of one *daṇḍa*, the *aṅguli* which as a unit has been used in several texts, can be converted in centimeters, i.e. 1 *aṅguli* ≈1.04167 cm.

From the above tables one can easily determine the size of a *paramāṇu*, which is equal to 0.4967 x 10^{-8} cm = 0.5 A, a well-known unit known as the Bohr unit in atomic physics.

6.2 Measurement of a Straight Line

In general, length is measured with the help of scales (*kāṣṭha*). These days, scales are marked with inches on one side, and centimeters on the other

The scale is placed on the line AB and the distance between these points shown by the scale is read as the length of the straight line. For observation a normal vision is necessary, or else wrong division may be observed (Fig. 2).

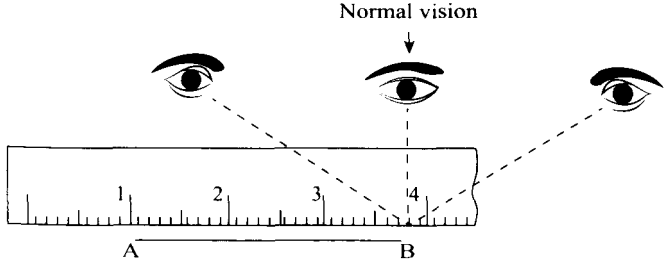


Fig. 2

6.3 Measurement of a Curved Line

The above said method is applicable only for straight lines. The methods for measurement of the length of curved lines are as follows:

6.3.1 Measurement with the Help of a Thread *(Tantu or Sūtra)*

The thread is spread over the curved line and marked on the first and last points of the curved line. The distance between these two marks is now determined with the help of the scale.

6.3.2 Measurement with the Help of a Divider *(Kārpāsaka)*

The two ends of a divider (*Kārpāsaka*) are kept two millimetres apart and placing one end at A and the other towards B, the divider is moved along the curve in walking fashion. Twice the steps required to place the divider to cover the curve is the length in millimetre. (see Fig. 3).

Fig. 3

6.3.3 Measurement with the Help of Calipers *(Vyāsamāpaka)*

The inner and outer diameters of hollow cylindrical and spherical bodies are determined by the calipers. The outer diameter of a solid sphere is determined by the distance between the ends of such spread so that it just allows to slip through the body.

For the inner diameter of a cylindrical hole, the ends are adjusted to their maximum separation so as to touch the inner surface. (Figs. 4-6).

The perimeter is given by the formula given below:

Circumference = $\pi \times$ (diameter)

The value of π is given in several ancient literatures (e.g. *Līlāvatī*).[4]

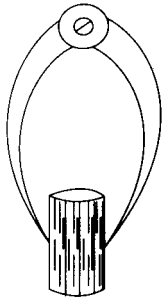


Fig. 4

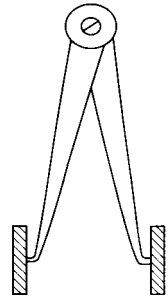


Fig. 5

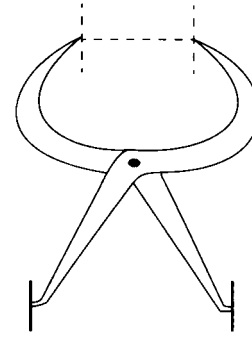


Fig. 6

6.4 Measurement of Area

The areas of a square, parallelogram, rectangle and circle are determined by the mathematical formulae given below:

Area of square	$= (\text{side})^2$
Area of rectangular surface	= length × breadth
Area of circular surface	$= \pi \times (\text{radius})^2$
Curved surface of a sphere	$= 4\pi \times (\text{radius})^2$
Curved surface of a cylinder	$= 2\pi \times (\text{radius}) \times (\text{length})$

$\therefore \pi = 22/7$ (approximate value)

or $\pi = 3927/1250$ (better value)

These formulae are given in numerous ancient Indian texts on mathematics. If the surface is irregular, then its shape is drawn over a graph paper with a proper scale; and the area is determined by counting the number of squares inside the irregular surface.

In counting elementary squares, the square of half or more than half of the elementary square is taken as a unit square.

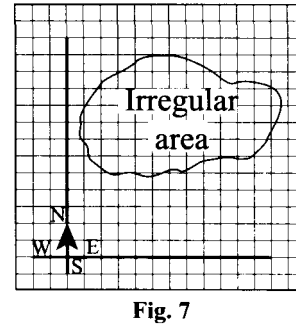


Fig. 7

6.5 Measurement of Volume *(Ghanaphaala Māpanam)*

The total space (*avakāśa*) occupied by a body is called its volume.

The volume (*ghanaphalaṁ*) of regular bodies is determined by the following formulae:

Cube	$= (\text{side})^3$
Rectangular solid	= length × breadth × height
Circular hole in a solid/ cylindrical hole	$= \pi \times (\text{radius})^2 \times (\text{length})$
Solid sphere	$= \pi/3 \times (\text{radius})^3$
Cone	$= \pi/3 \times (\text{radius})^2 \times (\text{length})$

The area and volume of circle and sphere are expressed in verse form in *Līlāvatī*[5].

The instruments generally used for the measurement of volume have been shown in Fig. 8. They are (a) graduated cylinder, (b) burette, (c) pipette, and (d) graduated flask.

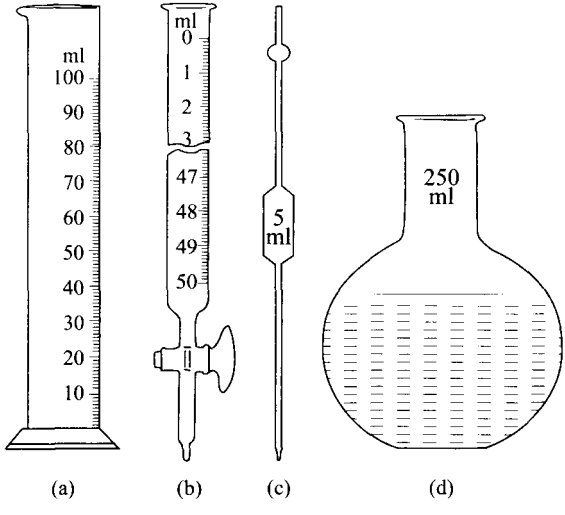


Fig. 8

6.5.1 Graduated Cylinder

An experimental body is immersed in water, which is taken in sufficient quantity in a graduated cylinder. The difference between the free liquid surfaces before and after the immersion is recorded. This difference is equal to the volume of the body.

If the experimental body floats on the water, the following method is adopted for the volume determination.

First a heavy body is taken. The position of the free surface of water after the immersion of the body is recorded. After that, the experimental body is tied to this and is immersed. Again the position of the free surface is recorded. The difference between these two records is the volume of the floating body.

If the substance of the body is soluble in water, any other liquid is taken in which the substance of the body is insoluble.

6.5.2 Burette

The volume of the small bodies like needles, lead pellets, etc. is determined with the help of a burette (Fig. 8b). The upper part of this instrument is graduated and the lower part is provided with a stopcock to regulate the flow of the liquid. The zero of the volume scale is marked on the top part of the burette. A beaker is taken and filled with water and its internal volume is determined with the help of the burette. Again a needle or lead pellet is placed inside the beaker and the volume of water required to fill the beaker is determined.

The difference of both the records gives the volume of the object.

6.5.3 Pipette and Graduated Flask

There are various sizes of pipettes and graduated flasks of fixed volumes. These are used to measure quantities of liquids.

The determination of volume is done through the records of the free surfaces of liquids in the concerned instruments. Depending upon the property of the liquid, the free surfaces are concave or convex. In all cases, the apex of the surface is read normally; if not, parallax error creeps into the observations.

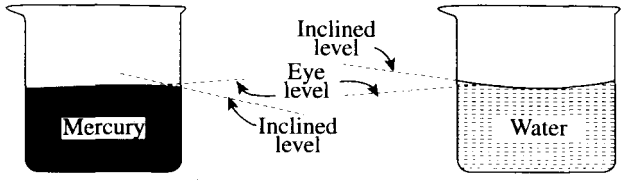


Fig. 9

6.6 Other Precise Instruments for Measuring Length

(a) Vernier Calipers (Fig. 10a)
(b) Screw Gauge (Fig. 10b)
(c) Spherometer (Fig. 10c)

These small handy instruments are used to measure length. The first two are theoretically and mathematically simple. Therefore, their detailed description is omitted.

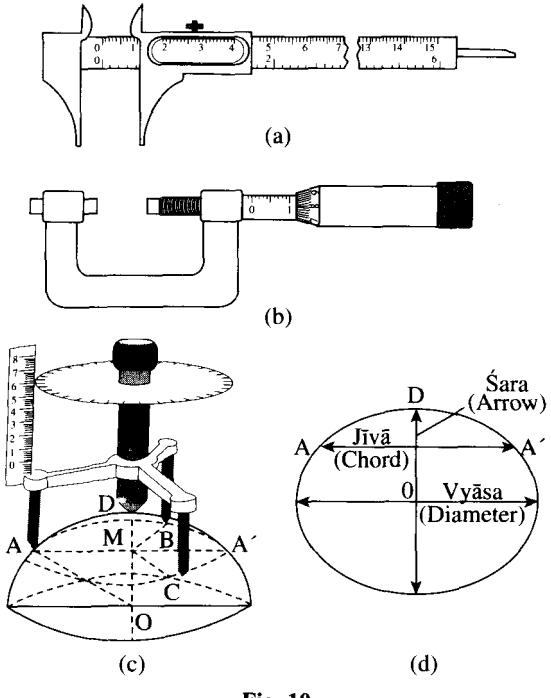


Fig. 10

Spherometer is shown in Fig. 10(c). This instrument rests on three legs A, B and C as shown. There is a fourth leg, D in the centre. The tips of the outer three legs are equidistant, and the central leg is symmetrical with respect to the outer legs. The central leg can be moved vertically with the help of a metallic circular plate.

First, all the four legs of the spherometer are brought in a plane and this is achieved by placing the instrument on a plane glass plate.

And then it is placed on the spherical surface for which radius of curvature is to be determined. Caution is taken to ensure that all the four legs just touch the spherical surface by moving the central leg upward as shown in Fig. 10(c). From the Fig. 10(d), it is obvious that the distance between the central leg and any of the other legs is 'a', half of the chord (*jiva*) of the circle 'ADA'. Again the central leg D through which it is moved upward by rotating the disc is measured with the help of the graduations on the scale and the disc together. If the distance is 'h', and known as *śara* (arrow) in Indian mathematics, the value of radius of curvature (*vakratārdhavāsa*) is given by:

$R = a^2/2h + h/2$

or, $2R = a^2/h + h$

or, diameter = (half of the chord)^2/ arrow + arrow

or *vyāsa* = (*jīvārdham*)^2/ *śara* + *śara*

The same formula has been given by Bhaskaracharya.[6]

Notes and Reference

1. *Sūrya Siddhānta*, p 264
   Ekasminyojane catvāraḥ krośāḥ pratikrośaḥ sahasradvayadaṇḍāḥ, pratidaṇḍaṁ catvāro hastāḥ, Ityādayaḥ
   (एकस्मिन्योजने चत्वारः क्रोशाः प्रतिक्रोशः सहस्रद्वयदण्डः, प्रतिदण्डं चत्वारो हस्ताः, इत्यादयः)।
2. *Sūrya Siddhānta, Madhyamādhikara*, 59
   Yojanāni śatānyaṣṭou bhūkarṇou dviguṇāni tu
   Tadvargato daśaguṇāt padaṁ bhūparidhirbhavet
   (योजनानि शतान्यष्टौ भूकर्णौ द्विगुणानि तु।
   तद्वर्गतो दशगुणात् पदं भूपरिधिर्भवेत्।)
3. *Bhojadeva, 'Samarāṅgaṇa Sūtradhāra' -Sūtrāṣṭakaṁ dṛṣṭi-nṛhastamoujaṁ kārpāsakaṁ syādavalaṁbasamjñaṁ. Kāṣṭhaṁ ca sṛṣṭyākhyāmato vilekhyamityaṣṭasūtrāṇi vadanti tajñāḥ*
   (सूत्राष्टकं दृष्टिनृहस्तमौजं कार्पासकं स्यादवलंबसंज्ञम्।
   काष्ठं च सृएटयाख्यमतो विलेख्यमित्यष्टसूत्राणि वदन्ति तज्ञाः।।)
4. *Līlāvatī*, 48 - *Vyāsebhanandāgnihate vibhakte khabāṇasūryaiḥ paridhiḥ sa sūkṣmaḥ Dvāviṁśatighne ca hate(a)tha śaile sthūlo(a) thavā syād vyavahārayogyaḥ*

(व्यासेभनन्दाग्निहते विभक्ते खबाणसूर्यैः परिधिः स सूक्ष्मः।
द्वाविंशतिघ्ने च हतेऽथ शैले स्थूलोऽथवा स्याद् व्यवहारयोग्यः।।)

5. *Vṛttakṣetre paridhiguṇita vyāsapādaṁ falaṁ tat*
Kṣuṇṇaṁ vedairupari patitaḥ kandukasyaiva jālaṁ

(वृत्तक्षेत्रे परिधिगुणित व्यासपादं फलं तत्)।
(क्षुण्णं वेदैरुपरि पतितः कन्दुकस्यैव जालम्)।

Golasyaivaṁ tadapi ca falaṁ pṛṣṭhajaṁ vyāsanighnaṁ
Ṣaḍbhirbhaktaṁ bhavati niyataṁ golagarbhe ghanākhyaṁ
(गोलस्यैवं तदपि च फलं पृष्ठजं व्यासनिघ्नम्)।
(षड्भिर्भक्तं भवति नियतं गोलगर्भे घनाख्यम्)।

6. *Līlāvatī - Jīvārdhavarge śarabhaktayukte*
vyāsaṁ pramāṇaṁ pravadanti vṛtte
(जीवार्धवर्गे शरभक्तयुक्ते व्यासं प्रमाणं प्रवदन्ति वृत्ते।)।

7

Pārthwaparimeyatvam: Measurement of Mass

7.1 Introduction

The quantity of matter is termed as mass. Before we discuss the measurement of mass, it is essential to compare and understand the concepts of matter in *Vaiśeṣika* as well as in physics.

While discussing material quantities (Chapters 3 and 4), we have considered solid, liquid and gas as three states of matter and the measure of matter is mass. The difference between these states depends upon the distance between their molecules. Though the above mentioned three states are temporal (*naimittika*), yet their study is possible. This study has theoretical importance. It investigates the physical conditions in which a solid changes into liquid or gas. *Vaiśeṣika* as it considers the solid, liquid and gaseous states as ideal or perfect states, it does not accept such transformation at *pañcamahābhūta* (or *tanmātrā* of *Sāṅkhya Darśana*) level, but at *bhuta* level, *Vaiśeṣika* considers it as temporal change. The word '*bhūta*' has a special meaning. *Bhūtas* are products of different intercombinations of *pañcamahābhūta* in accordance with the laws of *pañcīkaraṇa* are philosophical or ideal states of matter, while *bhūtas* depict the real states of matter. In physics, all the three states—solid, liquid and gaseous states are temporal. The states normally are not transformable and can be changed in appropriate temperature and pressure conditions.

The difference in the three states viz., solid, liquid and gas, is explained in physics by the difference in their intermolecular distance and molecular motion. Heating a solid increases molecular vibration and diminishes the cohesive forces, which, in turn decreases the hardness[1], elasticity, etc. At particular temperature and pressure, solid changes into liquid. In this state, the cohesive[2] forces give rise to the surface tension and due to this property, the liquid may take the shape of the container. If the liquid comes in the contact of more heat (*teja saṁyogaḥ*), the heating imparts more molecular motion to its molecules which overcomes the surface tension[3]; the molecules are freed to move on straight paths and, suffering collisions may follow zig-zag paths[4]. In this case, the molecular motion overcomes the gravity action appreciably, while in liquids gravity action is appreciable so that the falling of liquid is observed[5].

At definite pressure and temperature, the whole of the liquid may be converted into vapour. Such vapour (the gaseous state) shows increase or decrease in volume due to decrease or increase of pressure respectively. The above phenomena may be explained as follows:

Heat brings about a change in the intermolecular space of solid ice molecules, and changes solid ice into liquid water. The liquid water, again due to heat at definite temperature transforms into steam because of increase of molecular motion which, in turn, overcomes the surface tension.

In an experiment, if a small quantity of ice is taken inside a sealed vessel and heated on a balance, any change in mass in any state is not observed. Also, it shows that all the three states have mass which can be weighed by balance.

Thus, generalizing the above phenomena one may say that a matter may be transformed in different physical states and the quantity of matter is always conserved in transformations. This explains the presence of the properties like smell, gravity, etc. in all the three states. The action of the gravity imparts weight to the matter which depends upon the quantity of the matter. This quantity of the matter is termed as mass which can be measured with the help of a balance.

7.2 Units and Derived Units of Mass

From ancient scriptures like *Ṛgveda*, *Pāṇinī Aṣṭādhyāyī*, *Mahābhārata*, *Yājñavalkyasmṛti* and *Carakasaṁhitā*, we can describe weights and their denominations, which were in use in initial *Vaidika* period (1200-800 BC), as follows:

4 *māṣa*	= 1 *śāṇa*[6]
8 *śāṇa*	= 1 *śatamāna* (gold) = 320 *kṛṣṇala* (*ratti* or *guñja*)[7]
4 *śāṇa*	= 1 *suvarṇca*[8]
4 *suvarṇa*	= 1 *niṣka*[9]

From these, we may infer that:

1 *māṣa*	= 10 *kṛṣṇala*
16 *māṣa*	= 1 *suvarṇa* (*hiraṇya pala*).

Since *śāṇa* was the *paṇa*[10] (the coin) of this period, the Indian tradition is seen to be defining the referred '*pala*' in the context of a specific metal, as four times the *paṇa*. In this period, gold was the medium of exchange as in *Ṛgveda*, no mention of other metals for this purpose is observed.

Later (800 BC) in *Taittirīya Saṁhitā*, *Śatapatha Brāhmaṇa* and *Bṛhadāraṇyaka Upaniṣad* another '*śatamāna*' is described in connection with *yajña*[11], in which three *śatamāna* were given to every participant *brahmin*. It seems impracticable to consider *śatamāna* as a gold coin and it was more likely a silver coin. Kātyāyana[12] has given the weight of this coin as follows:

1 *śatamāna*	= 100 *kṛṣṇala*
1 *pada*	= 25 *kṛṣṇala*[13]

In the later period (500 BC) as in *Kāśikā*[14], a new *viṁśatika* standard was adopted:

1 *viṁśatika karṣa*

1 *viṁśatika karṣa* = 20 *suvarṇa māṣa* = 100 *kṛṣṇala*

1 *viṁśatika dharaṇa* = 20 *roupya māṣa* = 40 *kṛṣṇala*.

Around 400 BC another standard was introduced. According to this standard:

1 *karṣa* = 16 *suvarṇa māṣa* = 80 *kṛṣṇala*

In early 400 BC or later, all the weight standards which were used in India were very nicely summarised by Kauṭilya[15]. According to him:

1 *pala* (*āyamānī*)	= 10 *dharaṇa*
1 *pala* (*vyāvahārikī*)	= 9.5 *dharaṇa*
1 *pala* (*bhājanī*)	= 9 *dharaṇa*
1 *pala* (*antaḥpura bhājanī*)	= 8.5 *dharaṇa*

This information regarding the different weight standards and their denominations seems to be independent, and in different periods, different arbitrary choices of standards were in use.

Further, the above requires a scientific investigation; and if we do so, we may find a correlation between the different weight standards that were in use in India. One may also find the relation between Indian, Greek, Persian, Roman and British weight standards, and probably one may find that they were scientifically based on the *vaidik* weight standards, viz.:

1 *māṣa* = 10 *kṛṣṇala*

16 *māṣa* = 1 *suvarṇa* (the gold *pala*) (*vaidika pala*)

7.3 Scientific Investigation

Kauṭilya states that '*Sarvadhātūnām gourava vṛddhou satvavṛddhiḥ*'[16] which means that the increase in density (*gouravavṛddhiḥ*) is increase in matter/price (*sattva*) for all metals (*dhātu*) of equal volumes. In ancient times, metals were used for exchange in the form of coins (punch marked).

In order to retain the size and shape of the coins or blocks of different metals in accordance with their price, it is very likely that different weight standards referred to different metals were in use in ancient India. To keep their sizes comparable, one may define different units of weights (different *palas*) for different metals so that they may be inversely proportional to their respective densities. Considering the gold standard '*suvarṇa*' or *pala* of *vaidika* period as the basis of the other weight units, the '*pala*' referring to the specific

metals can be derived. For instance as the densities of gold, silver, copper and iron are 19.3, 10.5, 8.93 and 7.4 respectively, and this can be used to derive:

Silver *pala* =19.3/10.5 × *suvarṇa* =1.84 *suvarṇa*

Copper *pala* = 19.3/8.93 *suvarṇa* =2.15 *suvarṇa*

Iron *pala* = 9.3 × 7.4 *suvarṇa* = 2.5 *suvarṇa*

It appears that Indian system has approximated the density ratios to nearest whole numbers, and if we allow this, we find that:

Silver *pala* = copper *pala* = 2 × *suvarṇa*
= 2 × 16 *māṣa* = 32 *māṣa*,
and Iron *pala* = 3 × *suvarṇa* = 48 *māṣa*

Thus,

1 *dharaṇa* = 3.2 *māṣa* =32 *kṛṣṇala*

1 *karṣa* = 8 *māṣa* = 80 *kṛṣṇala*.

These units are the same as those Kauṭilīya describes as *Āyamānī* weight standard. Kauṭilya further describes various balances (*tulā*) in three sets and gives the sizes of iron rods and their weight in *louha* (iron) *pala*. Assuming, as a lay man, the diameters as 1, 2 and 2.5 *aṇguli* respectively, one may calculate the density of the iron in *māṣa* per cubic *aṇguli* unit, and tabulate as follows:

Set	Balance	Length in *aṇguli*	Weight in *pala* (iron)	Diameter in *aṇguli*	Density - *māṣa* per cubic *aṇguli* (m/ca)
1.	First ten balances having pans on both ends	8	1	1	7.64
2.	(*Samvrttā*)				
	Āyamānī	72	35	2	7.42
	Vyāvahārikī	66	33		7.64
	Bhājanī	60	31		7.89
	Antahpura bhājanī	54	29		8.20

Set	Balance	Length in *aṇguli*	Weight in *pala* (iron)	Diameter in *aṇguli*	Density - *māṣa* per cubic *aṇguli* (m/ca)
3.	(*Parimāṇī*)				
	Āyamānī	96	70	2.5	7.13
	Vyāvahārikī	90	68		7.39
	Bhājanī	84	66		7.68
	Antaḥpura bhājanī	78	64		8.02

Table 2

Mean density of iron for eighteen balances = 7.7 *māṣa* per cubic *aṇguli*.

Thus, we find that the numerical value of the density of iron in *māṣa* per cubic *aṇguli* is more or less the same as in gm/cc; therefore, māṣa should be the mass of one cubic *aṇguli* of water.

i.e. 1 *māṣa* = 1 cubic *aṇguli* of water
= $(1.04167)^3$ gms
= 1.13 gms = 17.5 grains

7.4 Indian, Greek, Persian and Roman Weight Standards

In ancient India (400 BC) one *Āyamānī Pala*, equal to 10 *dharaṇa*, was a well established unit of mass, which we have already obtained through the density ratio hypothesis. The other standards of weight have been described as *vyāvahārikī*, *bhājanī* and *antaḥpurabhājanī* of 9.5, 9 and 8.5 *dharaṇa*, respectively. In fact, these standards can be numerically obtained by considering the corresponding density ratios as 1:9, 1:8 and 1:7, respectively.

As the actual ratio of densities of gold and silver is 1:8, and *Bhājanī* standard is derived by this ratio, it seems that the name Bhājanī is derived from *bhajana* — the division. The contemporary Greek, Persian and Roman weight standards, as fixed by numismatists, seem to be *vyāvahārikī*, *bhājanī* and *antaḥpurabhājanī* respectively. This will be obvious from Table 3.

In Table 3, the numerical values given in brackets are the observed values of the coins as they have been fixed in numismatics. Before 400 BC, there was a weight standard named *viṁśatika karṣa* of 10 *māṣa* as stated above, which in turn, defines a *viṁśatika pala* of 40 *māṣa*, while *āyamānī pala* was of 32 *māṣa*. In western countries, before the advent of C.G.S or M.K.S system, *Avoirdupois* pound or British pound and Troy or *Apothecaries* pound were in use as the weight standards. Here, it will be interesting to note that these weights units are simply 10 *pala* weights of *viṁśatika* and *āyamānī* weights respectively as given below:

10 *viṁśatika*	= 400 *māṣa*	= 400 × 17.5 grains
	= 7000 grains	= 1 British pound
10 *Ayamānī pala*	= 320 *māṣa*	= 320 × 18 grains
	= 5760 grains	= 1 Troy pound

For Troy pound, 1 *māṣa* has been taken to be equal to 18 grains, instead of 17.5 grains. In Table 3, the difference in density ratio (1.8 ± 0.1) may be accounted for relative purities of the metals in different parts of the world, whereas Indians have rounded it to two, though they were having the knowledge of the correct ratio as they named that system as *bhājanī*. These calculations not only confirm the Indian unit of mass, *māṣa* to be a scientifically based unit like gramme, but also indicates a probable adoption by the others with slight modifications without mentioning *māṣa*, the Indian Unit of Mass.

In decimal system, the unit of mass is gramme (usually referred 'gram'), as the mass of water of one cubic centimeter at 4°C is called one gramme.

Gram is one thousandth part of the mass of platinum weight kept in Paris. The multiples and fractions are as follows:

10 milligram	= 1 centigram	10 gram	= 1 decagram
10 centigram	= 1 decigram	10 decagram	= 1 hectogram
10 decigram	= 1 gram	10 hectogram	= 1 kilogram

We have already seen that 1 *māṣa* = 10 *kṛṣṇala* = 1.13028 gms.

System	Density ratio (a)	Pala =(16a) *māṣa*	*Dharaṇa* = (5a)	Gold Coin Standard				Silver Coin Standard			
				Pala/n	Name	*Māṣa*	Grains	*Pala*/n	Name	*Māṣa*	Grain
Āyamānī (Indian)	2	32	10	*Pala*/4	*karṣa* (copper)	8	140 (144)	*Pala*/10	*dharaṇa*	3.2	56(56)
Vyāvahārikī (Greek)	1.9	30.4	9.5	*Pala*/8	*Drachm* (*Dram*)	3.8	66.5 (62)				
Bhājaṅī (Persian)	1.8	28.8	9	*Pala*/4	–	7.2	126 (130)	*Pala*/6	*siglos*	4.8	84 (86.4)
Antaḥpura-bhajani (Roman)	1.7	27.2	8.5	*Pala*/4	*Dinar aureus*	6.8	119 (120)				

Table 3

Thus, the mass described in various references in ancient Indian literature on material sciences may be expressed in gram, the modern unit of mass, which, in turn, may lead us to understand them with more clarity.

The standard of mass placed at Paris has been made of platinum metal. The selection of this metal is due to the reason that it is a noble metal (like gold) and it is not affected by weather changes.

In this regard, we can refer to Kauṭilya[17].

7.5 *Tulā* (Balance)

Weighing balance is used for comparing two masses. The construction of balances of various sizes is given in *Arthaśāstra* of Kauṭilya, which will be taken up in section 7.7. In order to understand the description given, we must recall the principle and working of a balance.

7.6 The Principle of Balance

A knife edge is fixed at the centre of wooden scale and is allowed to rest on a fulcrum. If the scale in not horizontal, the part which is tilted downward is filed (weight is reduced) till the scale becomes horizontal. Now the scale is graduated or marked with any equal distance or any unit of length. Two different weights (known) are suspended on either side of the scale (Fig. 11). Adjusting different distances of the weights, the scale is always brought in horizontal position and may be tabulated as follows:

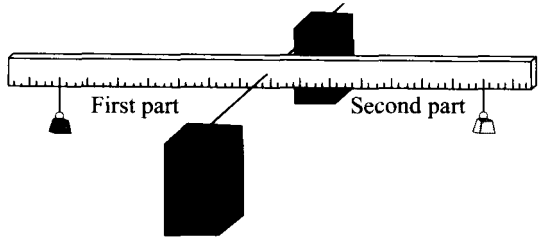


Fig. 11

Obs. No.	First part			Second part		
Observations when scale is horizontal	Distance from centre	Weight (Wt)	Wt. x distance	Distance from centre	Wt.	Wt. × distance
1	—	—	—	—	—	—
2	—	—	—	—	—	—
3	—	—	—	—	—	—
——	—	—	—	—	—	—

Table 4

We can now find that the product of weight and distance of one part is equal to that of the other part.

In a physical balance (see Fig. 12), the fulcrum is fixed at the middle of the beam and pans are provided on either side for weighing a body.

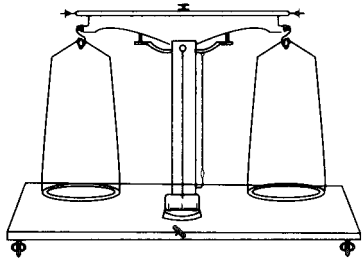


Fig. 12

7.7 The Balance of Kauṭilya

Kauṭilya[18] describes ten balance beams made of iron of 6, 14, 22, 30, 38, 46, 54, 62, 70 and 78 *aṅguli*, increasing their weights by one *pala*. The *pala* may be used on either sides of the instrument.

It is obvious from this short description, that Kauṭilya is describing the ten beams of lengths 6, 14, 22, 30, 38, 46, 54, 52, 70 and 78 *aṅguli*. As described in section 7.3, the density of iron is 7.70 *māṣa* per cubic *aṅguli*, the *māṣa* of 8 *aṅguli* length bar of unit cross-section will be 48 *māṣa* or 1 *louha pala* nearly, which is consistent with *sutra*[19]. He describes other types, like *samavṛttā* and *parimāni*. For example,

only *samavrtta tulā*[19] is considered here. According to this, we have to construct a bar of uniform cross-section of length 72 *aṅguli* and of weight 35 (*louha*-iron) *palas*. This bar is to be balanced with the help of a weight of 5 *pala*. For the use of the bar like the beam of balance, the bar should be suspended from the centre, with a hole drilled through it. If the bar does not rest horizontally, the bar may not be of uniform cross-section precisely or the hole may not be exactly at the centre. In such a case, a 5 *pala* weight is suspended to such a position (using it like a rider), where the beam becomes horizontal. Then it should be marked for 1 *karṣa* to 1 *pala*, 1 *pala* to 10 *pala*, 10 *pala*, 12 *pala*, 15 *pala* to 100 *pala* at the interval of 10 pala each. To facilitate the suspension of 5 *pala* weight, the small holes (*akṣa*) should be drilled at the places of the mark, and tagged with tug.

This description is very short. Applying the principle of the balance, this description must be mathematically analysed.

Considering the point where 5 *pala* weight, after suspension keeps the bar horizontal–as zero, one can mark the bar at one *aṅguli mānam* distance on either side. In practice; the body whose weight is to be determined, is suspended on the left side, and the weight (*pratimānam*) on the right side of the beam.

From *sūtra*[19], it appears that the balance has to be secured by placing 5 *pala* weight on different marks of the bar.

For example, let us consider that an experimental weight W is placed at mark 2 in the left, and corresponding balance is obtained when the 5 *pala* weight is placed at mark lain the right; then the experimental weight may be determined mathematically as follows:

Left part	Right part
W x 2	= 5 x 10
Therefore, W	= 25 *pala*

A similar calculation is done for whole of the length of the bar and presented in the Table 5.

R\L	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	5				1					1/2										1/4
2	10	5			2					1										
3	15		5		3										1					
4	20	10		5	4					2										1
5	25				5															
6	30	15	10		6	5				3					2					
7	35				7		5													
8	40	20		10	8			5		4										2
9	45		15		9				5						3					
10	50	25			10					5										
11	55				11						5									
12	60	30	20	15	12	10				6		5			4					3
13	65				13								5							
14	70	35			14		10			7				5						
15	75		25		15										5					
16	80	40		20	16			10		8						5				4
17	85				17												5			
18	90	45	30		18				10	9					6			5		
19	95				19														5	
20	100	50		25	20					10										5

Table 5

From the table it is obvious that if the 5 *pala* weight is placed, on the marks 10, 12,15, 20 respectively, then weighing 1 *karṣa*, 2 *karṣa*, 3 *karṣa*, etc. or 10, 12, 15, 20 *pala*, etc. is not possible.

In the *sūtra*[19], if a letter '*ta*' is introduced before *dvādaśa*; it becomes *tadvādaśa* which means, '*tat-vā-daśa*', i.e., a compromise with mathematics.

If this change is accepted and the experimental body is suspended at 20th mark on the left, the mark on the right at which balance is obtained gives the weight in *karṣa*. When the body is placed at mark 10 of the left, the mark at which the balance is obtained expresses the weight in half *pala* unit. In this way, if the body is placed at 1 *aṅguli*

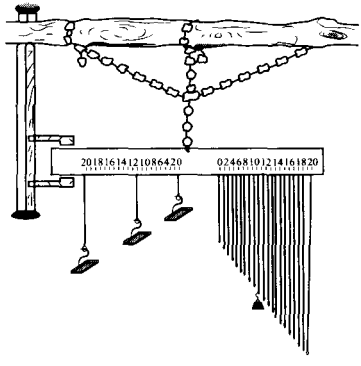
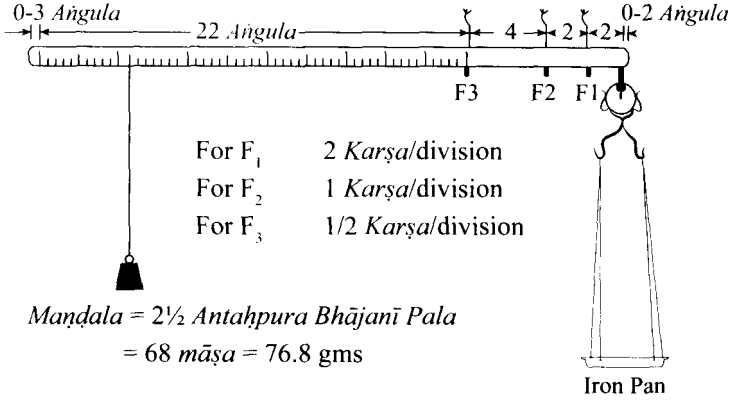


Fig. 13

(Fig. 13) mark on the left, the mark on the right will represent the weight as five times the number of balancing mark.

The form of *samavrtta tulā* is illustrated in the Fig. 13. A similar *tulā* has been exhibited at Patna Museumin the collection of Rāhul Sāṅkṛtyāyana (Fig.13 a)



ANTIQUE CHINESE YARD MISC. 10
(*Rāhul Sānṛtyāyana Kakṣa*, Patna Museum, India)

Fig. 13a

Thus, weights of different bodies were determined in ancient times on the same principles as we do today. The unit of mass defined in ancient India was related to the unit length for a standard substance, water, in the same way as favoured by the modern physicists.

Notes and References

1. B.P., p104, *Kāṭhinyādi kṣitaveva (काठिन्यादि क्षितावेव)*
2. P.B., pp 266, *Sneho(a)pāṁ viśeṣaguṇaḥ saṇgrahamṛjādihetuḥ (स्नेहोपां विशेषगुणः संग्रहमृजादिहेतुः)*
3. V.S., 2/1/2, *Rasasparśavatya āpo dravāḥ (रसस्पर्शवत्य आपो द्रवाः)*
4. V.S., 5/2/10, *Tatra visfurjjathūrlingaṁ (तत्र विस्फुर्ज्जथुर्लिंगम्)*
5. V.S., 5/2/14, *Agnerūrddhvajvalanaṁ vāyostiryak pavanamaṇūnāṁ manasascādyaṁ karmmādṛṣṭakāritaṁ (अग्नेरूद्ध्वंज्वलनं वायोस्तिर्यक् पवनमणूनां मनसस्चाद्यं कर्म्मादृष्टकारितम्)*

6. V.S., 5/1/1, *Saṁskārābhāve gurutvāt patanam (संस्काराभावे गुरुत्वात् पतनम्)* V.S., 5/2/3, *Apāṁ saṁyogābhāve gurutvāt patanaṁ (अपां संयोगाभावे गुरुत्वात् पतनम्)*
7. *Mahābhārata*, 3/136/15, *Āraṇyaka parva (आरण्यक पर्व)*
8. *Yājñavalkya Smṛti (याज्ञावल्क्य स्मृति)*, 1/364-365
9. Agrawal, Vasudeo Sharan, *Pāṇinikālīna Bhārata (पाणिनिकालीन भारत)*, p 252
10. *Manusmṛti (मनुस्मृति)* 8/137
11. *Pāṇinī Aṣṭādhyāyī (पाणिनि अष्टाध्यायी)*, 5/1/34
12. *Rathamocanīya Yajña, Rājasūya kāṇḍa, Śatapatha Brāhmaṇa (रथमोचनीय यज्ञ, राजसूय काण्ड, शतपथ ब्राह्मण)*, 5/1/34
13. *Kātyāyana Śroutasūtra (कात्यायन श्रौतसूत्र)*, 15/6/30
14. *Pāṇinī Aṣṭādhyāyī (पाणिनि अष्टाध्यायी)*, 5/1-/34
15. *Kātyāyana Śroutasūtra (कात्यायन श्रौतसूत्र)*, 15/6/30
16. *Kouṭilīya Arthaśāstra, Tulāmānapoutavaṁ, (कौटिलीय अर्थशास्त्र, तुलामानपौतवम्), Adhyāya* 19
17. *Kouṭilīya Arthaśāstra, Ākarakarmāntapoutavaṁ (कौटिलीय अर्थशास्त्र, आकरकमन्तिपौतवम्), Adhyāya* 19
18. *Partimānānyayomayāni māgadhamekala śailamayāni, yām vā nodakapradehābhyāṁ vṛddhiṁ gaccheyurūṣṇena vā hrāsaṁ (प्रतिमानान्ययोमयानि मागधमेकल शैलमयानि, याम् वा नोदकप्रदेहाभ्यां वृद्धिं गच्छेयुरूष्णेन वा ह्रासम्)* - *Kouṭilīya Arthaśastra* 39/19.
19 *Śadaṅgulādūrdhvamaṣṭāṅgulottarā daśa tulā kārayellouha palādūrdhvamekapaloottarāḥ yantramubhayataḥ śikyaṁ vā (षडङ्गुलादूर्ध्वमष्टांगुलोत्तरा दश तुला कारयेल्लौह-पलादूर्ध्वमेकपलोत्तराः यन्त्रमुभयतः शिक्यं वा)*, K.A.
20. *Pañcatriṁśat pala lohāṁ dvisaptatyaṅgulāyāmāṁ samavṛttāṁ kārayet. Tasyāḥ pañcapalikamaṇḍalṁ badhvā samakaraṇaṁ kārayet. Tataḥ karṣottaraṁ palaṁ palottaraṁ daśapalaṁ (ta) dvādaśa pañcadaśa vimśatiriti padāni kārayet. Tata āśatāddaśottaraṁ kārayet, akṣeṣu naddhrīpinadhaṁ kārayet (पञ्चत्रिंशत् पल लोहां द्विसप्तत्यंगुलायामां समवृत्तां कारयेत्। तस्याः पञ्चपलिकमंडलं बद्ध्वा समकरणं कारयेत्। ततः कर्षोत्तरं पलं पलोत्तरं दशपलं (त) द्वादश पञ्चदश विंशतिरिति पदानि कारयेत्। तत आशताद्दशोत्तरं कारयेत्। अक्षेषु नद्ध्रीपिनद्धं कारयेत्)*

8

Abvimarśaḥ: The Liquid State

Vaiśeṣika[1] considers liquid as colourless, cold, cohesive, and of perfect fluidity. According to physics, matter undergoes transformation into liquid and, therefore, smell exists due to concomitance. Liquids are mostly colourless. Liquids are cold (*śītasparśa*) due to evaporation. Liquid transforms into its gaseous form at every temperature; for this process, the required heat is absorbed from the liquid itself, hence, there is a lowering of temperature of the liquid. Due to adhesive force (*sneha*), liquids can be used to form pastes, or to knead the powders of solids. In fact, liquid molecules can always cover the particles of the powders of solids. In this changed condition, the particles come closer due to cohesive forces (*dravatva*) which, in turn, decrease the intermolecular spaces between solid particles and causes the particles to form pastes. *Dravatva* shows that molecules have cohesive forces; it also builds surface tension at the free surface of a liquid.

Fluidity is not eternal for real liquids. In nature, water normally occurs as liquid and, therefore, *Vaiśeṣika* has described it as representative of liquid state.

Metals like iron, gold, etc. at normal temperature and pressure exist in solid state. The conjunction of heat with metallic solids increases the molecular vibration to such an extent that solids may undergo transformation, and may form liquids of respective solids.

The properties like surface tension, viscosity, etc. which are due to *dravatva* have been studied in more detail in physics than that in the available texts of *Vaiśeṣika*. The inclusion of such studies will definitely elaborate the field of *Vaiśeṣika*.

Notes and References

1. *Vaiśeṣikaḥ jalasya viśeṣaguṇaḥ abhāswaraśuklarūpaṁ śītasparśaḥ (वैशेषिकः जलस्य विशेषगुणः अभास्वरशुक्लरूपं शीतस्पर्शः)।*

9

Vāyuvimarśaḥ: Gaseous State

The conjunction of heat with liquids causes an increase in translatory energies of the molecules resulting in a decrease in cohesive forces. Thus, the increase in kinetic energy of the molecules and the decrease in surface tension favours the swift vapourization of the liquid. At a definite temperature, for a given pressure, the heat absorbed is completely utilized in liquid-gas transformation. Such a gas is known as a real gas since normal variation in pressure and temperature may restore its liquid state. If the temperature of a real gas crosses the critical temperature, any effort in varying pressure cannot liquefy such form of the gas; and it is said that the gas is behaving like a perfect gas.

A gas possesses weight; a balloon when filled with air increases in weight. As gas is a state of matter, it has has smell and colour (e.g. chlorine). Thus, the matter in the gaseous state has smell.

Vaiśeṣika considers the temperature of a gas neither hot nor cold, since temperature, in general, is relative to the surrounding atmosphere. The conjunction or disjunction of heat with the gas may show rise or fall in temperature of the gas.

Different gases can be mixed together. The gaseous molecules of different gases due to conjunction of heat, may break into atoms and reconstitute new molecules of different properties. There is no doubt about this, since according to physics, gas is not a different physical entity but a state of matter. A real gas is made out of the molecules which are the constituents of a real liquid or a real solid. Therefore,

chemical reactions (*pīlūpāka*) are observed in gases also, like in solids (*Prthvī*). Gases, being matter, may exert large mechanical forces on obstructing bodies, e.g. due to pressure or wind velocity the motion of an arrow is resisted in air.

Ākāśa has been attributed with the property wave-aspect in general. *Vaiśeṣika* considers air as a medium (*vāhaka*) for acoustical waves (sound) which are perceived by ear. The propagation of sound has been discussed in Chapter 13.

It is important to note that *Vaiśeṣika* has not described the volume, mass, pressure and temperature of a gas, it has only done it qualitatively. The study of *Vaiśeṣika* can be elaborated with consideration of said properties of a gas with the aid of other contemporary literature on Āyurveda.

10

Kālaparimeyatvam: Time Measurement

10.1 Units of Time

Depending upon the motion of stars, Sun, Moon and other planets, and on mathematical derivations, *Sūrya Siddhānta* enumerates nine systems to measure time and, hence, nine units of time[1]. They are *brāhma*, *divya*, *pitrya*, *prājāpatya*, *gaurava*, *sour*, *sāvana*, *cāndra* and *ārkṣa*. The first six are used to define the time that elapses right from evolution of the universe; *cāndramāna* (lunar reckoning) is used to frame religious Hindu calendar to define rituals and festivals. *Sāvan dina* (solar day) and *nākṣatra dina* (sidereal day) are used to describe the planetary motion. Even in this age of modern science, we give importance to these two units of time. Solar day (*sāvan dina*), due to its usefulness, forms the basis of measurement of *kāla* (time) in both the systems.

In ancient Indian system, divisions and subdivisions of the units of time were as follows:

- 60 *vipala* = 1 *pala*
- 60 *pala* = 1 *ghaṭī (nāḍī/daṇḍa)*
- 2½ *ghaṭī* = 1 *horā* (hour)
- 24 *horā* = 1 *sāvanadina* (solar day)

In modern days, we follow the division and subdivisions for the units of time as follows:

- 60 seconds = 1 minute

- 60 minutes = 1 hour
- 24 hours = 1 solar day

The unit of time *horā* (equivalent to hour) gives the arrangement of the names of week days. According to Indian astronomy, every hour is called after the name of the *graha* (moving body, planet), in succession, as it appears from Earth; counting is done from the farthest to the closest. The number of planets (*grahas*) is seven considering the visibility to naked eye. We know these members of the solar system as Saturn (*Śani*), Jupiter (*Bṛhaspati*), Mars (*Maṇgala*), Earth's satellite Moon (*Soma*), Venus (*Śukra*), Mercury (*Budha*) and Sun (*Ravi*). By interchanging the position of the Sun, and the Earth with its satellite (Moon) in the above arrangement, the array of *grahas* as seen from Earth may be had in accordance with the list[2] of *grahas* as Saturn, Jupiter, Mars, Sun, Venus, Mercury and Moon. If, at the sunrise of a day, the first hour (*horā*) is that of Saturn, then the next hour (*horā*) will be of Jupiter, and so on. Continuing in cyclic order, the next morning *hour (horā)* will be of the Sun, on the succeeding day it will be of the Moon, and so on. The day is called after the name of the *graha* which is the master of the morning hour, i.e., the week lasts for only seven days[3], and then the days repeat in the same cycle, viz., *Śhanivāra* (Saturday), *Ravivāra* (Sunday), *Somavāra* (Monday), *Maṇgalvāra* (Tuesday), *Budhavāra* (Wednesday), *Bṛhaspativāra* (Thursday), and *Śukravāra* (Friday).

We will discuss *nākṣatra dina* (sidereal day) and *sāvana dina* (solar day) in the next section.

10.2 *Nākṣatradinaṁ* (Sidereal Day)

According to Āryabhaṭṭa[4], to a person in a boat, the objects on the banks of the river seem to be moving relatively opposite to him; similarly do the stars seem to move, since Earth is continuously rotating around its axis. Though the globe of Earth is rotating continuously; for the sake of mathematical simplicity, motion is imposed upon the stars, considering Earth to be at rest (*Achalā*)[5].

Indian astronomy defined a sidereal day as the time elapsed between two consecutive risings of the same star. According to physics, Earth rotates around its axis with a uniform angular velocity. Therefore, to an observer at the centre of Earth and moving with the Earth, the celestial sphere would appear to rotate with uniform angular velocity. One rotation of Earth around its axis, in terms of time, is called a sidereal day.

10.3 *Sāvandina or Kudina* (Solar Day)

If on a particular day, a planet is in conjunction with a star, the next day it will be slightly away from the star in the East[7]. Therefore, if the planet completes one revolution relative to the star, the total number of revolutions of the planet is one less than those of the star (see Chapter 5.9). The time required by the Sun (or a planet) to complete one round on the celestial sphere is termed as 'its one year' referred to the Sun (or to the planet).

The time required by the Sun between two successive rises is called one solar day. The ancients stated that the period of *Mahāyuga*, is covered by 43,20,000 solar years, For the same *Mahāyuga*, the number of sidereal days are 1,58,22,37,828. The number of solar days is given by the difference of the number of sidereal days to that of solar years since Sun completes one revolution per solar year.

Therefore, the solar days in one *Mahāyuga*

= Number of sidereal days – number of solar years
= 1582237828 – 4320000
= 1577917828

Therefore,

The number of solar days in one year (days, *ghaṭī*, *pala*)
= 1577917828/4320000 = 365.2587=365/15/30 – *(days/ghaṭī/pala)*
= 365¼ solar days

Similarly, the sidereal days in one solar year

= 1582237829/4320000 = 366.2587
= 366/15/30 – days /*ghaṭī* /*pala*
= 366 ¼ sidereal days

Thus, 365¼ solar days = 1 year = 366¼ sidereal days[10]

Notes and References

1. *Brāhmaṁ divyaṁ tathā pitryaṁprājāpatyaṁca gauravaṁ*
   Saurañca sāvanaṁ cāndraṁ ārkṣaṁ mānāni vai nava
   (बाह्मं दिव्यं तथा पित्र्यं प्राजापत्यं च गौरवम्)।
   सौरञ्च सावनं चान्द्रं आर्क्षं मानानि वै नव)।।
   –Sūrya Siddhānta, Mānādhyāya -1

2. *Tanmadhye bhramaṇaṁbhānamadhodhaḥ kramaśastathā*
   Manda-marejya-bhūputra-sūrya-śukrendujendavaḥ
   (तन्मध्ये भ्रमणं भानमधोधः क्रमशस्तथा)।
   मन्द मरेज्य-भूपुत्र-सूर्यशुक्रेन्दुजेन्दवः)।।
   –30, Bhūgolādhyāya, Sūrya Siddhānta

3. *Mandādaḥkrameṇa syuścaturthā divasādhipaḥ*
   (मन्दादधःक्रमेण स्युश्चतुर्था दिवसाधिपः)।
   –78, Bhūgolādhyāya, Sūrya Siddhānta

4. *Anulomagatirnausthaḥ paśyatyacalaṁ vilomagaṁ yadvat*
   Acalāni bhāni tadvat samapaścimagāni laṁkāyaṁ
   (अनुलोमगतिर्नौस्थः पश्यत्यचलम् विलोमगं यद्वत्।
   अचलानि भानि तद्वत् समपश्चिमगानि लंकायम्)
   –Golapādaḥ

5. *Madhye samantād daṇḍasya bhūgolo vyomni tiṣṭhati*
   Vibhrāṇaḥ paramāṁ śaktiṁ brahmaṇo dhāraṇātmikāṁ
   (मध्ये समन्ताद् दण्डस्य भूगोलो व्योम्नि तिष्ठति।)
   विभ्राणः परमां शक्तिं ब्रह्माणो धारणात्मिकाम्।।)
   –Bhūgolādhyāya, 32, Sūrya Siddhānta

6. See Article 101, *The Properties of Matter*

7. *Prāggatitvamatasteṣāṁ bhagaṇaiḥ pratyahaṁ gatiḥ*
   Pariṇāhavaśād bhinnā tadvaśād bhāni bhuñjate
   (प्राग्गतित्वमतस्तेषां भगणैः प्रत्यहं गतिः
   परिणाहवशाद् भिन्ना तद्वशाद् भानि भुञ्जते)।
   –Madhyamādhikāra, 26 –Sūrya Siddhānta

8. *Yuge sūryajñaśukrāṇāṁ khacatuṣkaradārṇavā*
   (युगे सूर्यज्ञशुक्राणां खचतुष्करदार्णवा।)
   –Madhyamādhikāra, 29, Sūrya Siddhānta

9. *Bhānāmaṣṭākṣivasvadritridvidvyaṣṭaśarendavaḥ.*
Bhodayā bhagaṇaiḥ svaiḥ svairūnāḥ svasvodayā yuge
(भानामष्टाक्षिवस्वद्रित्रिद्विद्व्यष्टशरेन्दवः।
भोदया भगणैः स्वैः स्वैरूनाः स्वस्वोदया युगे।।)
–Madhyamādhikāra, 34, Sūrya Siddhānta

10. See Chapter V on 'Time'- *The Properties of Matter*

11

Karma and Its *Sūtras*: Motion and Newton's Equations of Motion

11.1 *Karma* (Motion)

Vaiśeṣika[1] describes five types of *karma*; (i) upward motion (*utkṣepaṇa*) (ii) downward motion (*avakṣepaṇa*) (iii) shearing motion (*ākuñcana*) (iv) tensile motion (*prasāraṇa*) and (v) rectilinear motion (*gamana*). The causes for the first and second type of motions are gravity (*guruta*) and mechanical action (*prayatna*), the third and fourth are due to elastic and mechanical actions, and the fifth is due to mechanical action only.

With reference to the above types of motion, '*gamana karma*' seems to be the general term, which may include all other four types as its special cases. To explain this we may apply a simple logic. When a designation (*upādhi*) is imposed to a direction it becomes non-specific (*aniyata dik*) only. The *Vaiśeṣika* term *gamana*, i.e., the motion in unspecified direction (*aniyat dik*) can be treated as a general term for rectilinear motion of physics. Now, when a designation (*upādhi*) is imposed on the direction, viz., motion of the body in upward direction, motion of the body in downward direction, motion of the constitutive elementary parts of the body within it along an axis, or about it, the same *gamana* is specifically referred to as *utkṣepaṇa*, *avakṣepaṇa*, *ākuñcana* or *prasāraṇa* respectively.

Motion of a body depends on the *pārthivamānaṁ* (mass) and *gati* (velocity) of the body.

11.2 The Causes of *Karma*

The causes of *karma*, are mechanical force[2], force due to gravity[3], force due to elasticity[4], invisible force[5]', etc. Gravity is the force of attraction of the Earth on the body. The force acting between the molecules of the body is elastic force; and magnetic force is the force acting between iron and the magnet.

In Chapter 12, '*Vega saṁskāra*' has been described as mechanical force. According to *Vaiśeṣika*, *Vega* (force) is the cause for *Karma* (motion) and is also proportional to it. Now if the same force is applied on two bodies, the second being of double the mass of the first, the resultant velocity for the heavier body will be just half to that of the first for the same time interval.

11.3 Velocity *(Gati)*

Bodies move through space. The properties of the space are conjunction, disjunction, number and unit. All those put together will give us the position of the body relative to the point of observation.

If a body is moving along a straight line in space, and if at equal intervals of time, it is describing equal distances, the body will be said to be moving with uniform or constant velocity. Velocity (*gati*) is defined by the rate of change of distance described by the body.

The distance is measured by conjunction and disjunction with the marks placed in the direction, and the time, by a clock.

If a body describes distance 's' with uniform velocity throughout the time 't', the velocity = s/t Acceleration (*gati caya*) is defined as the rate of change of velocity.

If '*u*' is the initial velocity and '*v*' is the final velocity after an elapse of time '*t*', then the acceleration is given by:

$$a = v\text{-}u/t$$

11.4 Newton's Equations of Motion

These equations of motion can be easily derived by the application of the rules as stated in *Līlāvatī* by Bhāskarācārya.

11.4.1 The First Equation of Motion

If a body is under uniform acceleration '*a*', and '*u*' is the initial velocity when time is zero, then at the end of each second from the start, the velocity will be u, $u + a$, $u + 2a$, ... and so on.

If the final velocity is '*v*' and time of elapse be '*t*' then value of '*v*' will be given by the formula of Bhāskarācārya. Since the first term (*mukha*) is u, the number of terms (*pada*) is $(t + 1)$, common difference of the above series (*caya*) is a and the last term (*antya*) is v.

Therefore the last term = (one less the number of terms x common difference) + the first term

$$\text{i.e., } v = at + u = u + at$$

11.4.2 The Second Equation of Motion

This equation is to determine the distance described by the body in given time '*t*', if the body is under uniform acceleration, the distance described by the body will be equal to that described by the average velocity in time t. The average velocity is given by Bhāskarācārya's[7] formula as:

The average velocity (*madhya*) = [The first term (*mukha*) + last term (*antya*)] / 2

$$= (u + u + at)/2 = u + 1/2\ at$$

Therefore, the distance '*s*' described in time '*t*'

= (average velocity) x (time)

$$= (u + 1/2\ at)\ t = ut + 1/2\ at^2$$

or
$$s = ut + 1/2\ at$$

11.4.3 The Third Equation of Motion

The third equation is obtained by the elimination of 't' from the first two equations.

As from the first equation, we have:

$$t = v - u/a$$

Substituting the value of '*t*' in the second equation, we have:

$$s = u\ (v\text{-}u/a) + 1/2\ a\ (v\text{-}u/a)^2$$

or
$$v^2 = u^2 + 2as$$

In this way, we can derive the three equations of motion.

Notes and References

1. *Utkṣepaṇādīnāṁ pañcānāmapi karmatvasaṁbandhaḥ Ekadravyavatvaṁ, kṣaṇikatvaṁ, mūrtadravyavṛittitvaṁ, aguṇatvaṁ; gurutvadravatvasaṁyogaja tvaṁ,... asamāvayikāraṇatvaṁ; svaparāśrayasamavetakāryāraṁblakat vaṁ, samānajātīyānāraṁbhakatvaṁ ca pratiniyatajātiyogitvaṁ digviśiṣṭakāryārambhakatvaṁ ca viśeṣaḥ. Tatra utkṣepaṇaṁ śarīrāvayaveṣu tatsaṁbaddheṣu ca yadūrdhva-bhāgbhiḥ sṁyogakāraṇamadhobhāgbiṣca pradesaiḥ vibhāga-kāraṇaṁ karmotpadyate, gurutvaprayatnasaṁyogebhyaḥ tadutkṣepaṇaṁ. Tadviparītasaṁyogavibhāgakāraṇakarmāpakṣepaṇaṁ. Ṛjuno dravyasyāgrāvayavānāṁ taddeśairvibhāgaḥ saṁyogaśca mūla-pradeśairyena karmaṇāvayavī kuṭilaḥ sañjāyate tadākuñcanaṁ. Tadviparyayeṇa saṁyogavibhāgotpattau yena karmaṇāvayavī ṛjuḥ sampadyate tatprasāraṇaṁ. Yadaniyatadikpradeśasaṁyog-avibhāgakāraṇaṁ tadgamanamiti. Etat pañcavidhamapi karma śarīrāvayaveṣu tatsaṁbandheṣu ca satpratyaymasat pratyayaṁ ca yadenyastadapratyayameva teṣvanyeṣu ca tadgamanamiti.*

(उत्क्षेपणादीनां पञ्चानामपि कर्मत्वसंबन्धः। एकद्रव्यवत्वं, क्षणिकत्वं, मूर्तद्रव्यवृत्तित्वं, अगुणत्वं, गुरुत्वद्रवत्वसंयोगजत्वं,.... असमवायिकारणत्वं, स्वपराश्रयसमवेतकार्यारंभकत्वं, समानजातीयानारंभकत्वं च प्रतिनियतजातियोगित्वं दिग्विशिष्टकारंभकत्वं च विशेषः। तत्र उत्क्षेपणं शरीरावयवेषु तत्संबद्धेषु च यदूर्ध्वभाग्भिः संयोगकारणमधोभाग्भिश्च प्रदेशैः विभागकारणं कर्मोत्पद्यते, गुरुत्वप्रयत्नसंयोगेभ्य तदुत्क्षेपणम्। तद्विपरीतसंयोगविभागकारणकर्मापक्षेपणम्। ऋजुनो द्रव्यस्याग्रावयवानां तद्देशैर्विभागः संयोगश्च मूलप्रदेशैर्येन कर्मणावयवी कुटिलः संजायते तदाकुञ्चनम्। तद्विपर्ययेणम संयोगविभागोत्पत्तौ येन कर्मणावयवी ऋजुः सम्पद्यते तत्प्रसारणम्। यदनियतदिक्प्रदेशसंयोगविभागकारणम् तद्गमनमिति। एतत् पञ्चविधमपि कर्म शरीरावयवेषु तत्संबन्धेषु च सत्प्रत्ययमसत्प्रत्ययं च यदन्यस्तदप्रत्ययमेव तेष्वन्येषु च तद्गमनमिति)।

—P.B.

2. See Chapter 12
3. See Chapter 14
4. See Chapter 13
5. *Ayaso ayaskāntābhigamanavat tadupasarpaṇaṁ (अयसो अयस्कान्ताभिगमनवत् तदुपसर्पणम्)*

—N.S., 3-1-23.

6. *Maṇigamanaṁ sucyābhisarpaṇamadṛṣṭakāraṇaṁ*
(मणिगमनं सूच्याभिसर्पणमदृष्टकारणम् ।)

—V.S. 5-1-15.

7. *Vyaikapadaghanacayo mukhayuksyādantyadhanaṁ*
(व्यैकपदघनचयो मुखयुक्स्यादन्त्यधनम् ।)

—*Līlāvatī*

8. *Mukhayugdalitaṁ tat (antyadhanaṁ) madhyadhanaṁ*
मुखयुग्दलितं तत् (अन्त्यधनं) मध्यधनम् ।)

—*Līlāvatī*

12

Vega Saṁskāra: Mechanical Force and Newton's Laws of Motion

12.1 *Saṁskāra (Force)*

Praśastapāda Bhāṣya[1] enumerates the three forms of force (*saṁskāra*), viz. mechanical (*vega*), emotional (*bhāvanā*) and elastic (*sthitisthāpakatā*). *Bhāvanā* is the property of soul (*ātmā*). Elastic force will be considered in the next chapter. In this chapter, we will consider mechanical force (*vega*) only. The definition of mechanical force as given in *Praśastapāda Bhāṣya*[2] is as follows:

In all the five fundamental physical quantities (i.e, solid, liquid, gas, energy and mind of *Vaiśeṣika*) the mechanical force, or simply force is given as the cause and is proportional to motion (*karma*), caused by it to act in a given direction (as demanded by *karma*). Like temperature (*sparśa*), force also counteracts material conjunction, and sometimes one *vega* produces the other in series.

If the above definition be broken into three parts, we have the following characteristics of force:

(i) Force is specific cause for motion

(ii) Force is proportional to the motion produced and acts in the same direction, and

(iii) Force counteracts material conjunction and sometimes one (*vega*) produces the other in tandem.

These three constituents are the well-known Newton's laws of motion and would be obvious when these are supplemented with some explanation given in the following section.

12.2.1 The First Law of Motion

The meaning of the word '*vega*' can be found with the aid of Sanskrit grammar[4]. Accordingly, *vega* is equal to '*vejana*' and '*vejayati*' means that which causes a body to move. Thus, *vega* means the force. Force generates motion, i.e., a change in motion occurs till the force is active. This statement can easily be compared with Newton's first law of motion[5].

12.2.2 The Second Law of Motion[6]

This law provides a way for measuring force. So long as *vega saṁskāra* acts, increase in motion (momentum) is observed. In order to define its magnitude, consider the action in unit time, i.e. the change in motion (momentum) is to be considered in unit time. This consideration will be mathematically equivalent to the imposed force being directly proportional to the rate of change of momentum with the change taking place in the direction of the force.

Let '*m*' be the mass of a body, and the force acting upon the body changes its velocity (*gati*) from '*u*' to '*v*' in a period of time '*t*'. We have:

The initial momentum (*karma*)[7] $= mu$

The final momentum $= mv$

Therefore, the change in momentum $= m\,(v - u)$

Thus, the rate of change of momentum $= m\,(v - u)/t = ma$

from the first equation of motion (see Chapter 11).

From the second law of motion:

Force × rate of change of momentum

or $P \times ma$ or $E = K\,ma$ where, K is a constant.

Now, we can define the unit of force:

If $m = 1$, $a = 1$, then $1 = K \times 1 \times 1$ or $K = 1$

or $P = ma$

Thus, the unit of force may be defined as follows:

The unit of force is that which produces unit acceleration in a body of unit mass. In C.G.S. system, the unit of force is dyne, where one dyne is the force which, when acts on a body of mass 1 gram, produces an acceleration of 1 cm/sec^2.

12.2.3 The Third Law of Motion[8]

Kārya (reaction) is always in opposition to *Karma* (motion in action).

According to the third law of motion, the mutual actions of two bodies are always equal and act in opposite directions.

It states that in the direction in which the work is to be obtained, we shall exert force in the opposite direction. The examples are rowing of a boat, walking on the ground, climbing on a tree, flying birds in the air, etc. In all these cases, it will be observed that in order to have motion in desired direction, one has to exert force opposite to it. In the case of rowing a boat, water is pressed by the oars in a direction opposite to the direction of motion while during walking, the feet have to be pressed to the ground opposite to the direction of motion.

From the above examples, it is obvious that the reaction of an action is the only cause for the desired motion. In every case stated above, we find that if a body exerts on the other body, it counteracts upon the first. This reaction (*vega*) imparts motion to the first body in a direction opposite to that in which it has previously acted upon the second body. This is Newton's third law of motion.

12.2.4 Superiority over Newton's Laws

The statement of the definition of *Vega* (force) as given by *Vaiśeṣika* shows that the force is a physical quantity which is inferred by the motion and is only a means for the study of motion and not necessarily a really existing physical quantity. This concept of the force does not rule out the possibility of 'fictitious forces', a concept which arrives in the course of the study of Einstein's 'Theory of Relativity'.

Notes and References

1. *Saṁskārastrividha uktaḥ Vego-bhāvanā-sthithisthāpakaśceti (संस्कारस्त्रिविध उक्तः वेगो-भावना-स्थितिस्थापकश्चेति।)*

—P.B.

2. *Vego mūrtimatsu pañcasu dravyeṣu nimittaviśeṣāpekṣāt karmaṇo jāyate niyatadikkriyāprabandhahetuḥ, sparśavaddravyasaṁyogaviśeṣātvirodhi kvacitkāraṇaguṇapūrvakrameṇotpadyate*
(वेगो मूर्तिमत्सु पञ्चसु द्रव्येषु निमित्तविशेषापेक्षात् कर्मणो जायते नियतदिक्क्रियाप्रबन्धहेतुः स्पर्शवद्द्रव्यसंयोगविशेषात्विरोधि क्वचित्कारणगुणपूर्वक्रमेणोत्पद्यते)

—P.B.

3. *Atra – (i) Vegaḥ nimitta-viśeṣāt karmaṇo jayate*
(ii) *Vegaḥ apekṣāt karmaṇo jayate niyat dik-kriyā-prabandha hetuḥ*
(iii) *Vegaḥ samyogaviśeṣavirodhi, kvacitkāraṇaguṇapurvakrameṇot-padyate*
(अत्र – वेगः निमित्त-विशेषात् कर्मणो जायते)। वेगः अपेक्षात् कर्मणो जायते नियत दिक्-क्रिया-प्रबन्ध हेतुः। वेगः संयोगविशेषविरोधि, क्वचित्कारणगुणपूर्वक्रमेणोत्पद्यते)

—V.S. 1-1-14, *Kārya virodhi karma.* (*कार्यविरोधि कर्म।*)

4. *Vejanaṁ iti vegaḥ (वेजनं इति वेगः),*
Ovijibhyayacalanayoḥ vejayati cālayati iti vego iti
(ओविजिभ्ययचलनयोः वेजयति चालयति इति वेगो इति)।

—*A.K., Rāmāśramī Tīkā*

5. Every body (mass) continues in its state of rest or of uniform motion in a right (i.e. straight) line, unless it is compelled to change that state by force impressed upon it (*Principia*).

—W.U.E.

6. The change of motion is proportional to the motive force impressed and as made in the direction of the right line in which the force is impressed.

—*Principia*, W.U.E.

7. See Chapter 11.2

8. To every action there is always opposed and equal reaction, or the mutual action of two bodies upon each other are always equal and directed to contrary parts.

—*Principia*, W.W.E.

9. V.S. 1-1-14, *Kāryavirodhi karma* (*कार्य विरोधि कर्म*)।

13

Sthitisthāpakatā Saṁskāra: Elasticity

13.1 *Sthitisthāpakatā*

Sthitisthāpakatā[1] (elasticity) is a property (like temperature) of the bodies having densely populated elemental parts, by virtue of which, the bodies deformed (displaced or sheared) due to external deforming force recover their original shape and form after the removal of the deforming force.

If pressure is applied on a body, a resisting pressure known as *stress* is developed by the material. When the external deforming force ceases, this stress brings the body to its original position or shape. The stress is due to cohesive action between the molecules. The property by virtue of which this stress gets developed is known as elasticity.

The definition as expressed by *Vaiśeṣika* is not different from what is stated in physics. A detailed study is possible if experiments are carried out as in physics.

Physics deals with elasticity of linear or bulk shapes. At present, as there is no need for a detailed study of different types of elasticity, only linear elasticity by way of an example is explained here.

13.2 Linear Elasticity

If a wire is suspended by a hook fixed in the ceiling and the other end is loaded by a weight, it is found that, as the stretching load is increased in steps, the length also increases. When the weight is

removed the wire regains its original position. The stretching force cannot be increased infinitely. There is a limit above which, even after the removal of the load the wire does not regain its original form. Such a limit of weight is known as 'elastic limit'. If the weight is raised still further, then we may reach a value at which the wire breaks.

The increase in length within the elastic limit is found to be proportional to the stretching force, which must be equal to the force developed inside the material and is known as elastic force. This is an equivalent statement of the Hooke's law of elasticity.[3]

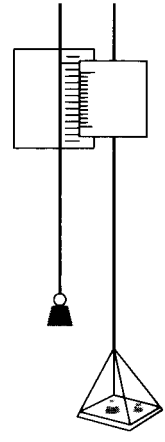


Fig. 14

Notes and Reference

1. *Sthitisthāpakastu sparśavaddravyeṣu vartamāno ghanāvayava-sanniveśa viśiṣṭeṣu kālāntaravasthāyiṣu svāśrayamanyathākṛtaṁ yathāvasthitaṁ sthāpayati*

   (स्थितिस्थापकस्तु स्पर्शवद्द्रव्येषु वर्तमानो घनावयवसन्निवेशविशिष्टेषु कालान्तरावस्थायिषु स्वाश्रयमन्यथाकृतं यथावस्थितं स्थापयति)

   —P.B.

2. *Ye ghanā niviḍā avayasanniveśāḥ tairviśiṣṭeṣu sparśavatsu dravyeṣu vartamānaḥ sthitisthāpakaḥ svāśrayamanyathā kṛtamavanāmitaṁ yathāvatsthāpayati pūrvavadṛjukaroti*

   (ये घना निविडा अवयवसन्निवेशाः तैर्विशिष्टेषु स्पर्शवत्सु द्रव्येषु वर्तमानः स्थितिस्थापकः स्वाश्रयमन्यथाकृतमवनामितं यथावत्स्थापयति पूर्ववदृजुकरोति)

   —N.K.T.

3. *Sthitishāpakasaṁskāraḥ kṣitaḥ keciccaturṣvapi kvacit spandepi kāraṇaṁ*

   (स्थितिस्थापकसंस्कारः क्षितः केचिच्चतुर्ष्वपि क्वचित् स्पन्देपि कारणम्)

   —159, B.P.

4. *Sthitisthāpaketi. Atīndriya iti. Ākṛṣṭaśākhādīnāṁ parityāge punargamanasya sthitisthāpakasādhyayatvāt. Keciditi. Caturṣu kṣityādiṣu sthitisthāpakaṁ kecinmanyante tadapramāṇamiti bhāvaḥ. Asau sthitisthāpakaḥ kvacidākṛṣṭaśākhādau iti*

   (स्थितिस्थापकेति। अतीन्द्रिय इति। आकृष्टशाखादीनाम् परित्यागे पुनर्गमनस्य स्थितिस्थापकसाध्यत्वात्। केचिदिति। चतुर्षु क्षित्यादिषु स्थितिस्थापकम् केचिन्मन्यन्ते तदप्रमाणमिति भावः। असौ स्थितिस्थापकः क्वचिदाकृष्टशाखादौ इति)

   —*Muktāvalī*

5. "Elasticity is a general name given to that property of a body in virtue of which it resists, and recovers from change of shape or volume. All substances resist changes in volume, and so have what is termed bulk elasticity, but it is only solids that have elasticity of shape; no fluid, liquid or gas can offer a permanent resistance to change of shape."
—Wagstaff in his *The Properties of Matter*

6. See *Pratyasathatā, Hindi Vishvakosha*, Vol. VII.

14

Gurutvavimarśaḥ: Gravity and Gravitation

14.1 *Gurutva* (Gravity)

According to *Vaiśeṣika,*[1] gravity is the cause for falling of solids and liquids. It is invisible, but can be inferred by the falling motion which is counteractive to material conjunction, effort and action of a force.

Further, perceptibility of *gurutva*, like other properties of a material depends on the size of the finer constituent parts under consideration.

When we consider a body falling under gravity[2], we have to assume that the finer constituent parts are also falling under gravity in order to maintain the logical quality between the body and its elemental parts.

In the light of above statement, one can easily arrive at a conclusion that gravity is the property of the elemental parts and, hence, of the body— a bigger body will also behave in the same way as a small body as far as the falling of the body under gravity is concerned.

The modern scientific world was ignorant of this fact till late 10th century, since Aristotle had taught that bodies fall at rates depending on their weight: that the heavier a body, the faster it should fall.

This doctrine remained undisputed till the time of Galileo (1590), who asserted that all bodies fall at the same rate, unless they are so light as to be impeded by the air resistance.[3]

In the description of the shape of Earth[4], *Sūrya Siddhānta* states that everyone considers oneself at the top of Earth in the space around

Earth. So for every body, downward direction is towards the centre of Earth. Thus, for every place on Earth, the falling of the body is always taking place towards the centre of Earth (see Fig. 15). If one raises the question why there is fall towards the Earth's centre? Bhāskarācārya[5] rightly provides the answer as below:

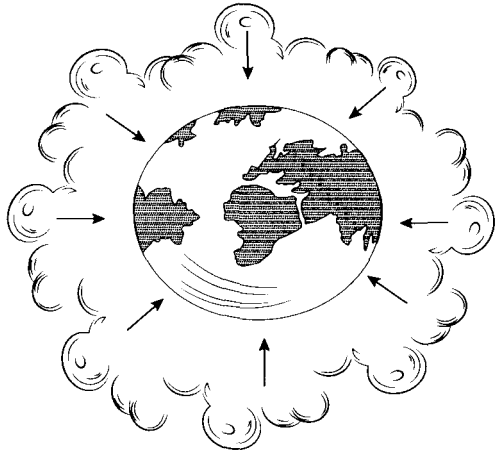


Fig. 15

"As Earth attracts a heavy body situated in the space towards it, the body also attracts Earth depending upon its heaviness. This attraction in turn is felt as falling; both being equal, which one of them is falling cannot be claimed." From the above statement, it is obvious that not only Earth, but other bodies also possess the property of attraction. When we generalize this type of attraction, we call it gravitation in physics, and when we are interested only with the force of attraction due to Earth, we call it gravity (*gurutva*)."

This law of force attraction acting between two bodies may be easily compared with that of Sir Issac Newton.[6] *Sūrya Siddhānta* describes planetary motion. A few assorted verses are given below for the benefit of the reader as a help to understand the views established in ancient India.

Paścādvrajanto(a)tijavānnakṣatraiḥ satataṁ grahāḥ,
Jīyamānāstu lambante tulyameva svamārgagaḥ-25

पश्चादव्रजन्तोऽतिजन्नक्षत्रैः सततं ग्रहाः।
जीयमानास्तु लम्बन्ते तुल्यमेव स्वमार्गगाः।।२५।।

Prāggatitvamatasteṣāṁ bhagaṇaiḥ pratyahaṁ gatiḥ.
Pariṇāhavaśādbhinnā tadvaśādbhāni bhuñjate-26

—Madhyamādhikāraḥ

प्राग्गतित्वमतस्तेषां भगणैः प्रत्यहं गतिः।
परिणाहवशाद्भिन्ना तद्वशाद्भानि भुञ्जतेः।।२६।।

(मध्यमाधिकारः)

Adṛśyarūpaḥ kālasya murtayo bhagaṇāśritaḥ
Śīghramandoccapātākhyā grahāṇāṁ gatihetavaḥ -1

अदृश्यरूपाः कालस्य मूर्तयो भगणाश्रिताः।
शीघ्रमन्दोच्चपाताख्या ग्रहाणां गतिहेतवः।।१।।

Tadvātaraśmibhirbaddhāstaiḥ savyetarapāṇibhiḥ
Prākpaścadapakṛṣyante yathāsannaṁ svadiṅmukhaṁ - 2

तद्वातरश्मिभिर्बद्धास्तैः सव्येतरपाणिभिः।
प्राक्पश्चादपकृष्यन्ते यथासन्नं स्वादिङ्मुखम्।।२।।

Pravahākhyo marut tāṁstu svoccābhimukhnamīrayet
Pūvāparāpakṛṣṭāste gatiṁ yānti prthagvidhaṁ - 3

प्रवहाख्यो मरुत् तांस्तु स्वोच्चाभिमुखमीरयेत्।
पूर्वापरापकृष्टास्ते गतिं यान्ति पृथग्विधाम्।।३।।

Grahātprāgbhagaṇārdhasthaḥ praṅmukhaṁ karṣati grahaṁ
Uccasaṁjño(a)parārdhasthastadvatpaścānmukhaṁ grahaṁ - 4

ग्रहात्प्राग्भगणार्धस्थः प्राङ्मुखं कर्षति ग्रहम्।
उच्चसंज्ञोऽपरार्धस्थस्तद्वत्पश्चान्मुखं ग्रहम्।।४।।

Uttarābhimukhaṁpāto vikṣipatyāparārdhagaḥ
Grahaṁ prāgbhagaṇārdhastho yāmyāyāmapakarṣati -7

उत्तराभिमुखंपातो विक्षिपत्यपरार्धगः।
ग्रहं प्राग्भगणार्धस्थो याम्यायामपकर्षति।।७।।

Mahattvānmaṇḍalasyārkaḥ svalpamevāpakṛṣyate.
Maṇḍalālpatayā candrastato bahvapakṛṣyate - 9

महत्त्वान्मण्डलस्यार्कः स्वल्पमेवापकृष्यते।
मण्डलाल्पतया चन्द्रस्ततो बह्वपकृष्यते।।९।।

Bhaumādayolpamūrtitvātcchīghramandoccasaṁjñkaiḥ
Daivatairapakṛṣyante sudūramativegitaḥ - 10

भौमादयोऽल्पमूर्तित्वाच्छीघ्रमन्दोच्चसंज्ञकैः।
दैवतैरपकृष्यन्ते सुदूरमतिवेगिताः।।१०।।

Ato dhanarṇaṁ sumahat teṣāṁ gativaśād bhavet
Ākṛṣyamāṇāstairevaṁ vyomni yāntyanilāhatāḥ - 11,

—Spaṣṭādhikāraḥ.

अतो धनर्णं सुमहात् गतिशाद्भवेत्।
आकृष्यमाणास्तैरेवं व्योम्नि यान्त्यनिलाहताः।।११।।

Dūrasthitaḥ svaśīghroccād grahaḥ śithilaraśmibhiḥ
Savyetarākṛṣṭatanurbhaved vakragatistadā - 52

दूरस्थितः स्वशीघ्रोच्चाद् ग्रहः शिथिलरश्मिभिः।
सव्येतराकृष्टतनुर्भवेद् वक्रगतिस्तदा।।५२।।

Bhāvābhāvāya lokānāṁ kalpaneyaṁ pradarśitā
Svamārgagāḥ prayantyete dūramanyonyamāśṛitāḥ. - 24

—Grahayutyadhikaraḥ.

भावाभावाय लोकानां कल्पनेयं प्रदर्शिता।
स्वमार्गगाः प्रयान्त्येते दूरमन्योऽन्यमाश्रिताः।।२४।।

(ग्रहयुत्यधिकारः)

Madhye samantādaṇḍasya bhūgolo vyomni tiṣṭhati
Vibhrāṇaḥ paramāṁ śaktiṁ brahmāṇo dharaṇātmikāṁ - 32

मध्ये समन्तादण्डस्य भूगोलो व्योम्नि तिष्ठति।
विभ्राणः परमां शक्तिं ब्रह्मणो धारणात्मिकाम्।।३२।।

Anyepi samasūtrasthā manyante(a)dhaḥ parasparaṁ
Bhadrāśvaketumālasthā laṅkāsiddhapurāsthitāḥ - 52

अन्येऽपि समसूत्रस्था मन्यन्तेऽधः परस्परम्।
भद्राश्वकेतुमालस्था लङ्कासिद्धपुराश्रिता।।५२।।

Sarvatraiva mahīgole svasthānam upari sthitaṁ
Manyante khe yato golastasya kvordhaṁ kva vāpyadhaḥ - 53

सर्वत्रैव महीगोले स्वस्थानमुपरि स्थितम्।
मन्यन्ते खे यतो गोलस्तस्य क्वोर्ध्वं क्व वाप्यधः।।५३।।

Bhūcakraṁ dhruvayorbaddhamākṣiptaṁ pravahānilaiḥ
Paryetyajasraṁ tannaddhā grahakakṣā yathākramaṁ - 73

भूचक्रं ध्रुवयोर्बद्धमाक्षिप्तं प्रवहानिलैः ।
पर्येत्यपस्रं तत्रद्धा ग्रहकक्षा यथाक्रमम् ।।७३।।

Uparisṭhasya mahatī kakṣā(a)lpādhaḥsthitasya ca
Mahatyā kakṣayā bhāgā mahānto(a)lpāstathā(a)lpaya - 75

उपरिष्ठस्य महती कक्षाऽल्पाऽधःस्थितस्य च
महत्या कक्षया भागा महान्तोऽल्पास्तथाऽल्पया ।।७५।।

Kālenālpena bhaganāṁ bhuṅkte(a)lipabhramaṇāśritaḥ
Grahāḥ kālena mahatā maṇḍale mahati bhraman - 76

कालेनाल्पेन भगणं भङ्क्तेऽल्पभ्रमणाश्रितः ।
ग्रहः कालेन महता मण्डले महति भ्रमन् ।।७६।।

Svalpayāto bahūn bhuṅkte bhaganān śītadidhītiḥ
Mahatyā kakṣayā gacchan tataḥ svalpaṁ śanaiścaraḥ - 77

—*Bhūgolādhyayah*

स्वल्पयाऽयो बहून् भुङ्क्ते भगवान् शीतदीधितिः ।
महत्या कक्षया गच्छन् ततः स्वल्पं शनैश्चरः ।।७७।।

The above verses describe general theoretical aspects of the celestial bodies. Further, *Sūrya Siddhānta* also gives the sizes and distances of the planets. Considering *Sūrya Siddhānta* and Astrophysics as the sources, a comparative study of the size of the Earth and inter-planetary distances has been presented in the following table.

Radius of Earth = $6.37 \times 10^8/800 = 8 \times 10^5$ cm

1 *yojana* = 8 kms

Sūrya Siddhānta	Astrophysics
Radius of the Earth = 800 *yojana* = 6.4×10^8 cms	Radius of Earth = 6.37×10^8 cms
Perimeter of the Earth = 5000 *yojana* = 4×10^9 cms	Perimeter of the Earth = 4×10^9 cms
Diameter of the Sun = 6500 *yojana* ∴ Radius = 3250 *yojana* = 2.6×10^9 cms	Radius of the Sun = 6.96×10^{10} cms
Diameter of the Moon = 480 *yojana* ∴ Radius of the Moon's orbit = 1.92×10^{10} cms	Radius of the Moon = 1.79×10^8 cms

Sūrya Siddhānta	Astrophysics
Perimeter of Moon's orbit = 324000 *yojana* ∴ Radius of Moon's = 4.1×10^{10} cms	Radius of Moon's orbit = 3.84×10^{10} cms
Perimeter of the Sun's orbit (considering the Earth at origin) = 4331500 *yojana* ∴ Radius of the Sun's orbit = 5.517×10^{11} cms	Radius of the Earth's orbit = 1.49×10^{13} cms The value is about 27 times larger than that by *Sūrya Sidhānta*
Distant stars are, at least at 60 times the distance of the son = $5.517 \times 10^{11} \times 60$ = 3.3×10^{13} cms	

Table 6

Sūrya Siddhānta	Astrophysics
Ākāśakaksā ardhavyāsa = 57753336000 *yojana* = 2.3×10^{21} cms	The distance of our Galaxy = 10^{23} cms
Ratio of Moon's orbit to Earth's radius $= \frac{51592}{800}$ = 64.5	Ratio of Moon's orbit to Earth's radius $= \frac{3.84 \times 10^{10}}{6.37 \times 10^{8}}$ = 60.3
Ratio of angular diameters of the Sun to that of the Earth $= \frac{6500}{1600} = 4.06 = 4.1$ i.e., approximately 4 times	Ratio of angular diameters of the Sun to that of the Earth $= \frac{6.96 \times 10^{10}}{6.37 \times 10^{8}} = 109.2$ i.e., approximately 109 times
Ratio of Sun's orbit Earth's radius $\frac{689729}{800} = 862.16$	Ratio of Sun's orbit to Earth's radius $= \frac{1.49 \times 10^{13}}{6.37 \times 10^{8}} = 23548$
Ratio of the size of Moon's orbit to Earth'a radius $= \frac{480}{2 \times 800} = 0.30$	Ratio of the size of Moon's orbit to Earth's radius $= \frac{1.74 \quad 10^{8}}{6.37 \times 10^{8}} = 0.27$

Sūrya Siddhānta	Astrophysics
Laws	Kepler's laws (1689 - 1619)
All planets move in circular orbit, considering the Earth at origin, their centre being slightly away from the origin. All planets move with equal velocities. The difference of the time period is due to the difference of the radius of orbits. Size of the planets affects the oscillation of the orbits in N-S direction.	All planets, including the earth, move around the Sun in elliptical orbits. There real velocities are constant. The square of the period of revolution round the Sun is proportional to the cube of the semi major axis of the ellipse. The above laws can be deduced from Newton's laws of Gravitation.

Table 7

whereas the size of Sun's disc, and the distance between the Sun and Earth are considerably different.

Sūrya Siddhānta	Astrophysics
Angular diameter $= \frac{8}{862.5} = \frac{1}{107.77}$ $= \frac{1}{108}$ radian	Angular diameter $= \frac{218}{23548}$ $= \frac{1}{108}$
Thus, the divergence in sizes does not affect the calculations for eclipses since angular diameters are the same.	
Ratio of the size of Sun to that of Moon $= \frac{6500}{480} = 13.5$	Ratio of the size of Sun to that of Moon $= \frac{6.96 \times 10^{10}}{1.74 \times 10^{8}} = 400$
Ratio of the radii of the orbits of Sun and Moon $= \frac{4331500}{324000} = 13.37$	Ratio of the radii of the orbits of Sun and Moon $= \frac{1.49 \times 10^{13}}{3.84 \times 10^{10}} = 388$
Thus, in both these systems, the sizes of the planets are proportional to the radius of their orbits (see Fig. 16)	

Table 8

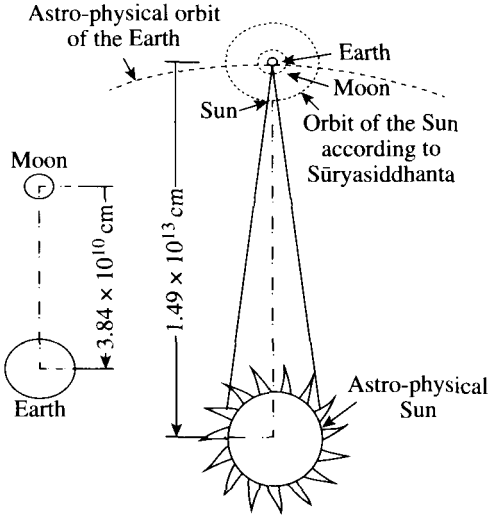


Fig. 16

Sūrya Siddhānta	Astrophysics
It considers the speed of the planets to be constant $= 1.09 \times 10^5$ cms/sec As speed of Moon in its orbit $= \frac{324 \times 8 \times 10^5}{2.36 \times 10^7}$ $= 1.09 \times 10^5$ cms/sec	It considers the velocity of light to be constant $= 2.998 \times 10^{10}$ cms/sec
Speed of Sun in its orbit $= \frac{4331500 \times 8 \times 10^5}{3.16 \times 10^7}$ $= 1.09 \times 10^5$ cms/sec	Speed of the Earth in its orbit $= \frac{2 \times 3.14 \times 1.49 \times 10^{13}}{3.10 \times 10^7 \times 10^5}$ $= 2.98 \times 10^5$ cms/sec^2
This requires further investigation.	

Table 9

Notes and References

1. *Gurutvaṁ jalabhūmyoḥ patanakarmakāraṇaṁ. Apratyakṣaṁ patana-karmānumeyaṁ saṁyogaprayatnasaṁskāravirodhi asya cābādiparamāṇurūpādivannityānnityatvaniṣpattayaḥ*

(गुरुत्वं जलभूम्योः पतनकर्मकारणम्। अप्रत्यक्षं पतनकर्मानुमेयं संयोगप्रयत्नसंस्कारविरोधि अस्य चाबादिपरमाणुरूपादिवन्नित्यान्नित्यत्वनिष्पत्तयः)

—P.B.

2. *Athāvayavānāṁ gurutvādeva tasya patanaṁ tadavayavānāmapi svāvayavagurutvāt patanamiti sarvatra kārye taducchedaḥ. Atha vyadhikaraṇebhyaḥ svāvayavagurutvebhyovayavānāṁ patana-saṁbhavāt teṣu gurutvaṁ kalpyate tadā avayavinyapi kalpanīyaṁ nyāyasya samānatvāt*
(अथावयवानां गुरुत्वादेव तस्य पतनं तदवयवानामपि स्वावयवगुरुत्वात् पतनमिति सर्वत्र कार्ये तदुच्छेदः। अथ व्यधिकरणेभ्यः स्वावयवगुरुत्वेभ्योऽवयवानां पतनसंभवात् तेषु गुरुत्वं कल्प्यते तदा अवयविन्यपि कल्पनीयं न्यायस्य समानत्वात्)।

—N.K.T.

3. See 'Gravity' - *The Properties of Matter.*
4. *Sarvatraiva mahīgole svasthānamupari sthitam*
Manyante khe yato golastasya kvordhvaṁ kvavāpyadhaḥ
(सर्वत्रैव महीगोले स्वस्थानमुपरि स्थितम्।
मन्यन्ते खे यतो गोलस्तस्य क्वोर्ध्वं क्वाप्यधः।)

—Sūrya Siddhānta, Bhūgolādhyāya

5. *Akṛṣṭisaktiśca mahī tathā yat, khastham gurum svābhimukham svaśaktyā*
Ākṛṣyate tat patatīva bhāti, same samatvāt kva patatviyaṁ khe
(आकृष्टिशक्तिश्च मही तथा यत्, खस्थं गुरुं स्वाभिमुखं स्वशक्त्या।
आकृष्यते तत्पततीव भाति, समे समत्वात् क्व पतत्वियं खे)

—Golādhyāyaḥ

6. Newton's Law of Universal Gravitation:
Every particle in the universe attracts every other particle with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

—Wagstaff, *The Properties of Matter*

15

Śabda: Wave Aspect

15.1 *Śabda*

As we have already seen in Chapter 4 and 5, plasma is the fourth state of matter. According to *Vaiśeṣika,* the specific property of plasma is the wave aspect. This property is permanent to this state. It is important to note that while dealing with microscopic particles in physics, one is forced to consider the wave aspect of these particles. *Vaiśeṣika,* which sets its ultimate goal as the study of *Ātmā* and *Mana* (soul and mind), turns to explain *'kṣaṇik śabda'* as 'sound' (acoustical wave) which is sensed by the ear.

Vaiśeṣika[1] considers air as a medium *(vāhaka)* for sound. It is obvious that for the process of sound propagation through air, the air molecules should execute *spanda* (oscillations at their mean position), i.e., periodic conjunctions and disjunctions. It is natural to assume that the vibrations within the intermolecular spaces arise due to the existence of plasmatic states within the molecules. Moreover, sound is of two kinds (i) musical sound *(dhvani)* and (ii) speech consonant *(varṇa).* Their definitions are in accordance with modern physics.

The propagation of sound in space can be explained with the analogy of the waves on the free surface of water. Every point on the wavefront becomes the cause for the next wavefront,[2] and is exactly parallel to Huygen's construction for the new wavefront. They have considered two types of wave propagation in accordance to (i) *Kadaṁbagolanyāya* (longitudinal mode) and (ii) *Vīcītaraṅganyāya*

(transverse model). For further details of musical instruments, etc., we may refer to other ancient literatures on *Sāma* and *Saṇgīta.*

Notes and References

1. *Śabdo(a)ṁbaraguṇāḥ śrotragrāhyaḥ kṣaṇikaḥ kāryakāraṇo-bhayavirodhī saṁyogavibhāgaśabdajaḥ pradeśavṛttiḥ samānāsamānajātīyakāraṇaḥ. Sa dvividho varṇalakṣaṇo dhvanilakṣaṇaśca. Tatra ākārādirvarṇalakṣaṇaḥ śaṅkhā-dinimittadhvanilakṣaṇaśca. Tatra varṇalakṣaṇasyotpattir-ātmamanasoḥ saṁyogāt smṛtyāpekṣāt varṇoccāraṇecchā tadanantaraṁ prayatnastamapekṣamānādātmavāyu saṁyogād vāyau karma jāyate sa corrdhvaṁ gacchan kaṇṭhādin ābhīhanti tataḥ sthānavāyusaṁyogāpekṣamānāt sthānākāśasaṁyogāt varṇotpattiḥ. Avarṇalakṣaṇopi bheridaṇḍasaṁhyogāpekṣād bheryākāśayogādutpadyate. Veṇuparva vibhāgād venvākāśavibhāgācca saṁyogavibhagaṇiṣpannādvīcīsantāna-vacchabdasantāna ityevaṁ santānena śrotrapradeśamāgatya grahaṇaṁ śrotraśabdayorgamanāgamanabhāvād aprāptasya grahaṇaṁ nāsti pariśeṣāt santānasiddhiriti.*

   (शब्दो अंबर गुणः श्रोत्रग्राह्यः क्षणिकः कार्यकारणोभयविरोधी संयोगविभागशब्दजः प्रदेशवृत्तिः समानासमानजातीय कारणः। स द्विविधो वर्णलक्षणो ध्वनिलक्षणश्च। तत्र आकारादिर्वर्णलक्षणः शंखादि निमित्तध्वनि लक्षणश्च। तत्र वर्णलक्षणस्योत्पत्तिरात्ममनसोः संयोगात् स्मृत्यपेक्षात्वर्णोच्चारणेच्छा तदनन्तरं प्रयत्नस्थमपेक्षमानादात्मवायुसंयोगाद्वायौ कर्म जायते स चोर्ध्वं गच्छन् कण्ठादीन् अभिहन्ति ततः स्थानवायुसंयोगापेक्षमानात् स्थानाकाशसंयोगात् वर्णोत्पत्तिः। अवर्णलक्षणोपि भेरिदण्डसंयोगापेक्षाद् भेर्याकाशसंयोगादुत्पद्यते। वेणुपर्वविभागाद्वेण्वाकाशविभागाच्च संयोगविभागनिष्पन्ना-द्वीचीसन्तानवच्छब्द सन्तान इत्येवं सन्तानेन श्रोत्रप्रदेशमागत्य ग्रहणं श्रोत्रशब्दयोर्गमनागमनभावादप्राप्तस्य ग्रहणं नास्ति परिशेषात् सन्तानसिद्धिरिति।)

   -Śabdaguṇa Vimarśaḥ

2. *Śabdāt saṁyogavibhāganiṣpannād vīcīsantānavacchabdasantāno yatha jalavīcyātodavyavahite deśe vīcyantaramupajāyate tatopyanyat tatopyanyad ityanena krameṇa vīcīsantāno bhavati tatha śabdādutpannāt tadvyavahite deśe śabdantaram tato(a)-pyanayorgamanāgamana bhāvāt prāptasyarivopalabdhiriti tato(a)pyanyat tato(a)pyanyad ityanena krameṇa śabda santāno bhavati*

(शब्दात् संयोगविभागनिष्पन्नाद्वीचीसन्तानवच्छब्दसन्तानो यथा जलवीच्यातोदव्यवहिते देशे वीच्यन्तरमुपजायते ततोप्यन्यत् ततोप्यन्यदित्यनेन क्रमेण वीचीसन्तानो भवति तथा शब्दादुत्पन्नात् तद्व्यवहिते देशे शब्दान्तरं ततोप्यनयोर्गमनागमनभावात् प्राप्तस्यइवोपलब्धिरिति ततोप्यन्यत् ततोप्यन्यदित्यनेन क्रमेण शब्दसन्तानो भवति।)

—N. K.T.

3. Physics deals wave motion in detail. For the detailed study see *'Waves and Oscillation' by Dr. N. G. Dongre*

16

Teja: Energy

16.1 *Teja*

According to *Vaiśeṣika*[1], *teja* possesses a bright illuminance. It is atomic by nature. The energy imparts heat sensation, so the bodies in conjunction with energy quanta attain a high temperature. The conjunction of energy quantum brings the change in motion[2] and chemical reactions[3] are due to conjunction of energy quanta, and vice versa.

Material obstructions are of two kinds: some are like wooden planks, such as to stop the passage (absorption), while others are glass *(kāca)* like materials which allow energy to pass through (refraction). The colours in a body are seen due to the conjunctional effects (scattering) of energy quanta viz. photons.

16.2 Sources of Energy

Vaiśeṣika describes *Bhoumaṁ* (terrestrial) and *Divyaṁ* (celestial) as the sources[4] of energy. The other two, viz. *Udaryaṁ* (abdominal) and *Ākarajaṁ* (mineral) are related to metaphysical quantities. *Bhoumaṁ* and *Divyaṁ* have been described as heat and light in physics, their properties being temperature and colour, respectively.

The invisible causal factors of the motion of iron needle towards magnets (Chapter 11.2) and the effects of electricity (Chapter 4, footnote 4) are also different forms of energy. The detailed study of all these are the causes for the development of modern physics. It is possible to conduct studies separately on the analytical descriptions of heat, light, electricity and magnetism.

According to the ancient literature, *śabda* is of two kinds. One is *āhata nāda* (wave in a material medium), and the other is *anāhata*

nāda (probably wave aspect of the matter). If the study of *śabda* (wave aspect) is done on the basis of both *Vaiśeṣika* and physics, it will provide a way for enlightened discussions.

This work intends to show the parallelism existing between the physical quantities of *Vaiśeṣika* and those of the modern physics. So far, physical quantities of real existence have been taken into account. To complete the comparison, we proceed to investigate the remaining four logical physical quantities, namely *Sāmānya, Viśeṣa, Samavāya, and Abhāva.*

Notes and Reference

1. *Tatra śuklaṁ bhāsvaraṁ ca rūpaṁ. Ūṣṇa eva sparśaḥ*
   (तत्र शुक्लं भास्वरं च रूपम्। ऊष्ण एव स्पर्शः।)

   —*P.B.*

2. *Ghaṭāderāmadravyasyāginnā sambaddhasyāgnyābhidhānātnodanā dvā tadārambhakeṣvaṇuṣu karmāṇyutpādyante*
   (घटादेरामद्रव्यस्याग्निना संबद्धस्याग्न्याभिधानात्नोदनाद्वा तदारंभकेष्वणुषु कर्माण्युत्पाद्यन्ते।)

   —*P.B.*

3. *Punaranyasmādagnisaṁyogādauṣṇyapekṣāt pākajā jāyante*
   (पुनरन्यस्मादग्निसंयोगादौष्ण्यपेक्षात् पाकजा जायन्ते।)

   —*P.B.*

4. *Bhaumaṁ divyamudaryamākarajaṁ ca. Tatra bhaumaṁ kāṣṭhendhanaprabhavamūrdhvajvalanasvabhāvaṁ. Pacana-dahana-svedanādi-samartha divyamabindhanaṁ sauravidyudādi*
   (भौमं दिव्यमुदर्यमाकरजं च। तत्र भौमं काष्ठेन्धनप्रभवमूर्ध्वज्वलन-स्वभावं, पचन-दहन-स्वेदनादिसमर्थ दिव्यमबिन्धनं सौरविद्युदादि)

   —*P.B.*

17

Sāmānya, Viśeṣa, Samavāya and *Abhāva:* The Mathematical Expressions

17.1 *Sāmānya* (Set)

The cause of assimilative cognition is called *sāmānya* (set)[1]. The physical quantities having similarity or uniformity of shape or kind form a set. *Vaiśeṣika* describes the three sets[2] as universal set *(parasāmānya),* subset *(parāparasāmānya)* and element *(aparasāmānya).* Further, *Vaiśeṣika* gives examples of these categories as physical quantity *(bhāvapadārtha),* fundamental physical quantity *(dravya),* and an earthern pot *(ghaṭa),* respectively.

We will use this concept of sets to elaborate further discussions. In mathematics, numbers may be considered to form a set and one can develop arithmetical operations like addition, subtraction etc., forming subsets and elements (classes).

Algebrical quantities may form sets of different kinds. By assigning physical meaning to these algebrical quantities and correlating them with numbers, one can develop algebra. We know that the addition or subtraction of quantities of same species or physical quantities is logically possible. If, for example, at one place there are 4 human beings, 15 cows and 6 buffaloes, i.e. there are in all 25 sentient beings, and 21 of them are animals. In this example, we may classify this set into a universal set as sentient beings, one subset as animals with elements as cow and buffalo and another subset as human being. Similarly, if at another place, there are 2 human beings, 3 cows and

5 buffaloes, by applying the addition operator on these two sets, the numbers of sentients, human beings and animals can be obtained by adding the qualifying numbers of universal set, elements and subset. If the same numbers of the element are removed from the first set, the difference is to be considered. This can be algebraically transformed as follows:

If we have S for sentient being, H for human being, C for Cow, B for Buffalo and A for animal, then:

The first set	= 4 H + 15 C + 6 B
and the second set	= 2 H + 3 C + 5 B
Their sum	= 6 H + 18 C + 11 B
and the difference	= 2 H+ 12 C + B

If the count of sentient beings is required, S being the universal set, algebraically we have H = S, C = 2 and B = 2

Therefore, on substitution we can get the total count of sentients

= 6 S + 18 S + 11 S = 35 S = 35 sentient beings.

Similarly, the total number of animals (animal forming a subset) can be obtained if we substitute:

A = C and A = B; then the total number of animals

= 18 A + 11 A = 29 A = 29 animals and so on.

Thus, we may conclude that the use of mathematics by itself considers *sāmānya* (set).

17.2 *Viśeṣa* (Specific)[3]

The cause of cognition of ultimate difference is called *viśeṣa* (specific). *Viśeṣa* is the central concept of *Vaiśeṣika* philosophy, and that is why it is known as *Vaiśeṣika Darśana.* The physical quantity bearing *viśeṣa* (ultimate and partless character) is termed as *dravya* (fundamental physical quantity). According to *Vaiśeṣika,* such partiess quantities are *ākāśa* (plasma), *dik* (length vector), *kāla* (time), *ātmā* (soul), and atoms of *pṛthvī* (solid), *ap* (liquid), *teja* (radiant energy), *vāyu* (gas), and *mana* (mind).

As considered already, physics holds the opinion that solid, liquid, gas and plasma are mere states of matter and energy, and may mutually transform into each other; therefore, they represent

a single measurable fundamental physical quantity, 'mass'. This mass can dwell in space-time continuum *(vibhu)* and therefore, the measurement of length vector and time become the second and third fundamental physical quantities, respectively. In physics—mass, length vector and time are the three fundamental physical quantities. This classification has essentially the same basis as that of *Vaiśeṣika,* namely the ultimate and partless character.

On the basis of *dravya* (the fundamental physical quantities), *guṇa* (properties) and *karma* (motion), are studied employing simple algebric expressions and all other physical quantities may be easily expressed, as exemplified below:

Let, mass = M, length = L and time = T

Area = $L \times L = L^2$

Volume = $L \times L \times L = L^3$

Velocity = $L/T = LT^{-1}$

The right hand sides of the above expressions are termed as dimensional formulae. It is important to note that the physical quantities having the same dimensions possess similarity and therefore, they form a set *(sāmānya).*

17.3 *Samavāya* (Concomitance)

Samavāya[4] is defined as a physical quantity existing non-conjunctively between the inheritor and the inherited. This concomitance explains a relation between the fundamental physical quantities and their properties, as well as the motion pertaining to them. According to *Vaiśeṣika,* in general, there are two relations: one is conjunctive *(saṁyoga)* and the other is concomitative *(samavāya).* Temporary and momentary relation between any two substances is known as conjunctive relation. Boat and river relation is an example of conjunctive relation. Similarly, the relation between the fundamental physical quantity (say *teja)* and corresponding one of the properties (say *sparśa)* is an example of concomitative relation.

Concomitance, the non-conjunctive and eternal relation, which is altogether different from the conjunctive relation, is the relation

of parts with the whole, the properties and the motions with the fundamental physical quantities, elements with sets, and specific with fundamental physical quantity.

Concomitance can be expressed by a mathematical relation and can be stated as follows:

The conjunction of heat energy *(teja)* with a substance (matter) gives an experience of hotness *(uṣṇatva)* in the body.

Energy and hotness being a fundamental physical quantity *(dravya)* and its property *(guṇa)* respectively, have a concomitative relation.

Discussion

While discussing the property *'sparśa'* (temperature), it is said that it can be divided in three parts as cold, medium and hot.

If water is taken in a container and heated gradually, a consequent gradual rise in volume of water is observed. In the same fashion, mercury (Hg) is also seen to expand on heating and contract on cooling. The hotness or coldness of mercury is due to concomitance of heat energy. The expansion of mercury can be used to measure the hotness or temperature of a body. Physics utilizes this property to construct a simple thermometer, the instrument used to measure temperature *(sparśa)*.

To measure temperature, a unit is required and two standard temperatures are necessary. The two such standard temperatures are, of the fixed conditions of hotness at which the change of state of water occurs from liquid state to ice formation (solid state), and that at which liquid water converts into steam at 'normal' atmospheric pressure. These two points are known as freezing and boiling points of water. Between these two temperatures, by dividing the expansion observed in, say, mercury, a temperature scale is obtained.

If the distance between these two marks registered in the capillary of the thermometer by expansion of mercury is divided into hundred parts, every part will be said to be equal to one degree centigrade, the lowest mark being at zero of this temperature scale.

From the above discussion, it is obvious that with the conjunction of heat, matter shows hotness and its grade may be determined by

the use of such a thermometer. When such a thermometer is kept in contact with the substance under experiment, the mercury level rises in the capillary. The value of the mark at which it reaches gives the temperature, which is given by this number *(saṅkhyā)* along with the unit *(parimāṇa*-degree centigrade).

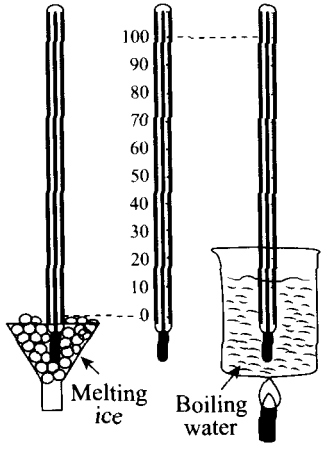


Fig. 17

The same thermometer, when brought into contact with two substances one after the other, gives the temperatures of both on this scale. If the scale reads more for one substance than for the other, the first substance is hotter than the other. Conversely, if the temperature is less, the body is colder.

If the same amount of heat energy is supplied to two different masses of the same substance, the rise in temperature observed is not the same. For a large mass, greater amount of heat is required to have the same rise in temperature, i.e., a greater amount of heat should be in conjunction with the substance; however, the rise or fall of temperature is observed with the conjunction or disjunction of heat energy with the substance, showing concomitance of temperature with heat.

The above effects can be mathematically expressed as:

Heat = H, Mass = M and the Rise in temperature = T

(i) Heat is directly proportional to mass due to conjunctive relation, i.e.,

$$H \times M$$

(ii) Heat is directly proportional to rise of temperature due to concomitative relation, i.e.,

$$H \times T$$

Therefore, from the laws of mathematics, we have

$$H \times MT$$

or, $$H = SMT$$

where S is a constant (specific heat) dependent on the properties of the substance.

17.4 Ancient Scale of Temperature: *Liṅka*

Baroda State Library has in its possession a manuscript of the section *Vaimānika Prakaraṇa* of *'Yantra Sarvasva'* of Maharshi Bhāradvāja. *'Vaimānika Prakaraṇa'*, i.e. the aeoronautic section also has a commentary written by Bodhānanda. In that section, several techniques related to this topic have been described, out of which one is *'Karṣaṇa Rahasyam'*; i.e. Gundown Technique. The text[5] may be literally translated as follows:

Cannon ball placed inside the cumbustion chamber = वेश्वानरनालान्तर्गत *(Vaiśvānaranālāntargata)*—situated at the head of the aeroplane = विमानाभिमुखस्थ *(vimānābhimukhastha)* should be heated up to eighty seven *'Liṅka'* magnitude of hotness = सप्ताशीतिलिंकप्रमाणोष्णं यथा भवेत् *(saptāśiti paramānoṣṇāṁ yathābhavet)*, by burning fuel = ज्वालिनीप्रज्वालनं कृत्वा *(jvālinīprajvālanaṁ kṛtvā)*, then allowing the motion of a lever connected to a pair of wheels = तथा चक्रद्वयकिलीचालनात् *(tathā cakradvayakilīchālanat)*, imparting spin to the ball aimed = वर्तुलाकारेण तत्शक्तिप्रसारणद्वारा *(vartulākāreṇa tatcchaktiprasāraṇadvārā)*, — on the foe's aeroplane = शत्रुविमानोपरि *(śatruvimānopari)*. This describes the technique to 'gun down' the foe's aeroplane = शत्रुविमाननाशनक्रियारहस्यम् *(śatruvimānanāśanakriyārahasyam)*.

It will be interesting here to note that in ancient India, probably there was a temperature scale named *liṅka*, in use. Perhaps, *liṅka*, being a technical term, was not common in use; and that is perhaps

the reason, we have not come across this word in other available Sanskrit literature. However, the meaning of the word *liṅka* can easily be derived with the help of Sanskrit grammar and *Vaiśeṣika Darśana.* In Sanskrit *'laḥ'* meant 50, which reminds that the Roman numeral 'L' also represents 50. In this way a common origin of the words 'lah' and 'L' can be established. Thus, the word *liṅka* derived from *laḥ* can well mean a scale of temperature having 50 parts. In modern scientific world, centigrade unit of temperature bears similar meaning, as a scale of 100 parts.

In order to define a temperature scale, three things are essential, namely, two (lower and higher) standard temperatures, and the number of divisions to be made between these two standard temperatures. In the centigrade and *liṅka* systems, as their names signify, the number of divisions are 100 and 50 respectively. We know that for the centigrade scale, the lower and higher standard temperatures are the freezing and boiling points of water at mean sea level. In order to arrive at such standard temperatures in ancient India one has to draw inferences from some other ancient Indian literatures. According to *Vaiśeṣika, śītasparsa* (coldness) and *ūṣṇasparśa* (hotness) dwell in *Ap* (liquid) and *teja* (energy) respectively. The representative materials of these are water and gold. As *dravatva* (fluidity) is also a common property of both *Ap* and *Teja,* one can easily arrive at the conclusion, that the freezing point of water and melting point of gold may have been considered as the lower and higher standard temperatures, respectively. Thus, *'liṅka* scale' should have 50 divisions between the freezing point of water and the melting point of gold.

As the freezing point of water and melting point of gold on centigrade scale are 0°C and 1062°C, the rise in one *liṅka* is equivalent to 1062/50 = 21.24°C. This provides us a way to estimate the temperature 87 *liṅka* cited in the above reference[5], which will be equal to 87 x 21.24 = 1850°C, a temperature at which materials when heated will have a white glow. This inference seems to be consistent with the reference, as heating up to 87 *liṅka* will mean the heating of canon ball to glowing whiteness and then throwing over the foe's aeroplane.

Further, as *liṅka* scale is a moderately high unit, a unit may be assumed as 24th part of *liṅka* (author's view), and let us name it as *Praliṅka* (PL), which will be nearly equivalent to 0.885°C. On this scale, the boiling point of water and the melting point of the gold will become 113°PL and 1200°PL, respectively, zero point being at the freezing point of water.

These facts are depicted in Fig. 18. Here, it is obvious that the relation for conversion of temperature may be written as:

Comparison of Temperature Scales

$$\frac{C}{100} = \frac{PL}{113}$$

	Modern scientific degree Centrigrade (1/100) system	Ancient Indian degree *Liṅka* (1 /50) system
Melting point of gold	1062°C	1200°PL .....50°L
Boiling point of water	100°C	113°PL
Melting point of ice	0°C	0°PL .....0°L
Absolute zero	-273°C	-308°P

Symbol	**Conversion**
C - Centrigrade	1°L = 21.24°C
L - *Liṅka*	1°L = 24°PL
PL - *Praliṅka*	1°PL = 0.885°C

Table 10

The inclusion of *praliṅka* by the author serves a purpose. The unit of heat defined in scientific work is a calorie in C.G.S system, which is the amount of heat required to raise the temperature of 1gm of water by 1°C, where the specific heat of water is assumed to be unity.

Therefore:

Heat = 1gm x 1°C = 1 Calorie.

Similarly, we may define the unit of heat in ancient system.

H Cal = 1 *māṣa* x 1°PL = 1.13 gm x 0.885°C = 1 Cal

This brings about equivalance of the units of heat in both the systems. Thus, it is obvious that the expression:

$$H = SMT$$

will hold good in both the systems, where 'S'; the specific heat of a material will have the same numerical value in both the systems.

In this way, this mathematical expression gives the relation of heat energy with matter and temperature. The concomitance of temperature with heat is also obvious from this relation.

17.5 *Abhāva* (Absence)

In *Vaiśeṣika Sūtra, Maharṣi Kaṇāda* has not included *abhāva* while enumerating *padārthas,* but has mentioned it in certain *sutras.* The only authentic commentary on *Vaiśeṣika Sūtra* is *Praśastapāda Bhāṣya* which considers it important and explains it throughly[6]. A mere look on a mathematical relation cannot throw any light on the relations amongst the physical quantities involved, and the consideration of *abhāva* only decides the nature of the relation (whether it is conjunctive or concomitative) between the physical quantities.

According to *Praśastapāda Bhāṣya, abhāva* (absence) is of two kinds (i) *Saṁsargābhāva* (absence of relation) and (ii) *anyonyābhāva (absence of identity).*

The perception of no coldness in heat energy is due to relational absence of coldness. The perception of no identity between the conjunctional substances is the absence of identity.

(i) Relational Absence *(Saṁsargābhāvaḥ)*

Relational absence is divided[7] as (a) Antecedent, (b) Consequent, and (c) Absolute absence.

(a) Antecedent absence *(prāgabhāvaḥ)* is absence of effect prior to cause coming into existence, as absence of earthen pot in soil.

(b) Consequent absence *(pradhvamsābhavaḥ)* is absence of effect subsequent to its passing out of its existence, as absence of earthen pot after it has been destroyed.

(c) Absolute absence *(atyantābhāvaḥ)* is the absence which is present prior, subsequent, and in between conditions of its existence. This cannot be produced, nor destroyed. Absolute absence of quantity is where its opposite cannot reside, e.g. absence of coldness in heat energy.

Now let us investigate the mathematical equation $H=SMT$ in the light of *abhāva* (absence).

(a) Antecedent absence – The absence of rise of temperature prior to heat energy coming into conjunction with matter, i.e., when heat energy is equal to zero, from the equation, we get

$$0 = SMT$$

In this equation when $H = 0$, it does not mean that mass is zero, since heat has to come into conjunction with matter, therefore, $T = 0$, i.e., the rise in temperature is zero; hence the absence of rise of temperature.

(b) Consequent absence – If H amount of heat produces a rise of temperature T, and if no more heat is supplied to the substance, no more rise in temperature will be observed. As the cause of rise of temperature i.e., heat has stopped, no subsequent rise in temperature (effect) occurs, i.e., the absence of rise of temperature (effect). This is consequent absence.

(c) Absolute absence – From the above equation, it is obvious that increase in heat is accompanied by rise in temperature, i.e., the experience of increase in hotness and not in coldness. So there is absolute absence in increase of coldness.

(ii) Identitive Absence *(Anyonyābhāvaḥ)*

As long as the physical state of matter is fixed, both the heat and the matter are independent of each other in so far as the amount of heat and mass are concerned, since neither the mass is converting into heat energy, nor the heat energy into mass. In such a case, heat is not mass and vice-versa, i.e., there is identitive absence of heat in mass, or conversely, there is identitive absence of mass in heat energy.

So, we may conclude that a mathematical equation can express *sāmānya, viśeṣa, samavāya* and *abhāva.* By this methodology, physics

can express quantitatively and precisely getting rid of complicating, and numerally non-conclusive language.

Notes and References

1. *Anuvṛttipratyayakāraṇatvaṁ sāmānyatvaṁ*
   (अनुवृत्तिप्रत्ययकारणत्वं सामान्यत्वम्)

   —*N.K.T.*

2. *Ākāraprakāraikyasādharmyādibodhakāranṇabhūtā yā jātiḥ sāmānya-padena vyapadiṣyate. Vyāpyatvavyāpakatvādinā sāmānyasya vaiśeṣikadarśane trayo bhedāḥ samāmnātāḥ santi: 1. paraṁ, 2.aparaṁ, 3.paramaparaṁ ceti. Sāmānyeṣu paratvāparatvaparāparatvāṇāṁ gamakāni teṣāṁ vyāpyatvavyāpyakatvavyāpyavyapakatvāni sama-bhyupagamyante. Sattāyāḥ vyāpakatvāttasya paratvaṁ, ghatatvasya vyāpyatvāttasyāparatvaṁ, dravyatvasya vyāpyatve sati vyāpakatvāt parāparatvaṁ cāvagamyate.*

   (आकारप्रकारैक्यसाधर्म्यादिबोधकारणभूता या जातिः सामान्यपदेन व्यपदिष्यते। व्याप्यत्वव्यापकत्वादिना सामान्यस्य वैशषिकदर्शने त्रयो भेदाः समाम्नाताः सन्ति (१) परम् (२) अपरम् (३) परमपरं चेति। सामान्येषु परत्वापरत्वपरापरत्वाणां गमकानि तेषां व्याप्यत्वव्याप्यकत्वव्याप्यव्यपकत्वानि समभ्युपगम्यन्ते। सत्तयाः व्यापकत्वात्तस्या परत्वं, घटत्वस्य व्याप्यत्वात्तस्यापरत्वं, द्रव्यत्वस्य व्याप्यत्वे सति व्यापकत्वात् परापरत्वं चावगम्यते।)

   Sādharmyavahāṁ samānajātīyānāṁ padārthānāṁ yogaḥ antaraṁ ca bhavitumarhati

   (साधर्म्यवहां समानजातीयानां पदार्थानां योगः अन्तरं च भवितुमर्हति।)

   —V.G.V., p. 104

3. *Atyantavyāvṛttibuddhiheturviśeṣa iti viśeṣoyaṁ sāmānyat sarvathā pratipopadārthaviśeṣosti. Viśeṣasyāsya vaiśiṣtyādevāsya darśanasya (vaiśeṣikadarśanasya) vaiśeṣika iti nāmnā bhṛśmanvarthakatvaṁ saṁjuṣate. Yad dravyaṁ niravayavatvādhāreṇa nityamasti tasya vaisiṣtyaṁ hi viśeṣa iti samprati sampratipadyate. Niravayavā etādṛśāḥ padārthā ākāśakāladigātmānaḥ prthivyaptejovāyūnāṁ paramāṇavaḥ manaśca*

   (अत्यन्तव्यावृत्तिबुद्धिहेतुर्विशेष इति विशेषोयं सामान्यात् सर्वथा प्रतिपोपदार्थविशेषोस्ति। विशेषस्यास्य वैशिष्ट्यादेवास्य दर्शनस्य (वैशेषिकदर्शनस्य) वैशेषिक इति नाम्ना

bhṛśamanvarthakatvaṁ saṁjuṣate। yad् dravyaṁ niravayavatvādhāreṇa nityamasti tasya vaiśiṣṭyaṁ hi viśeṣa iti saṁprati saṁpratipadyate। niravayavā etādṛśaḥ padārthā ākāśakāladigātmānaḥ pṛthivyaptejovāyūnāṁ paramāṇavaḥ manaśca)।

4. *Ayuta siddhayogāśrayāsrayībhāvaḥ samavāya iti*
(अयुतसिद्धयोगाश्रयाश्रयीभावः समवाय इति)

—*N.K.T.*

Eṣassamavāyaḥ tanniṣṭhaguṇakarmaṇāṁ cādhārādheyabhāvamūlakaṁ sambandhaṁ sfuṭīkāaroti. Vaiśeṣikamatānusāreṇa sāmānyatayā dvau sambandhau parijñāyete, tau ca saṁyogaḥ samavāyaśceti. Vastudvayasyāsthāyitayā tātkālikaḥ mithasambandhaḥ saṁyogaśabdena vyapadiśyate. Sambandhoyaṁ saṁyogaḥ kṣaṇikonityaśca bhavati, yathā vā tarīnadyossambandhassaṁyogatvena pratipāditosti. Ādhārādheyabhūteṣu padārthadvayeṣu saṁyogoyaṁ guṇatvena tiṣṭhatīti kṛtvā saṁyogasambhandhaḥ yutasiddho bhavati

(एषस्समवायः तन्निष्ठगुणकर्मणां चाधाराधेयभावमूलकं संबन्धं स्फुटीकरोति। वैशेषिकमतानुसारेण सामान्यतया द्वौ सम्बन्धौ परिज्ञायेते, तौ च सयोगः समवायश्चेति। वस्तुद्वयस्यास्थायितया तात्कालिकः मिथस्संबन्धः संयोगशब्देन व्यपदिश्यते। संबन्धोयं संयोगः क्षणिकोनित्यश्च भवति, यथा वा तरीनद्योस्संबंन्धस्संयोगत्वेन प्रतिपादितोस्ति। आधाराधेयभूतेषु पदार्थद्वयेषु संयोगोयं गुणत्वेन तिष्ठतीति कृत्वा संयोगसंबन्धः युतसिद्धो भवति)।

—V.G.V.

5. *Vaiśvānaranālāntargata vimānābhimukhastha jvālinīṁ prajvālanaṁ kṛtva saptāśīti linka pramāṇoṣṇaṁ yatha bhavet tathā cakra - dvayakilīcālanāt vartulākāreṇa tatchakti prasāraṇadvārā śatruvimānopari, satruvimānanāśana kriyā rahasyaṁ*

(वैश्वानरनालान्तर्गत विमानाभिमुखस्थ ज्वालिनीं प्रज्वालनं कृत्वा सप्ताशीति लिंक प्रमाणोष्णं यथा भवेत् तथा चक्रद्वयकिलीचालनात्, वर्तुलाकारेण तत्छक्तिप्रसारणा द्वारा शत्रुविमानोपरि, शत्रुविमाननाशनक्रियारहस्यम्)।

6. *Abhāvo hi dvividhaḥ samākhyātosti*
(अभावो हि द्विविधः समाख्यातोस्ति)।

(i) Saṁsargābhāvaḥ (संसर्गाभावः) (ii) Anyonyābhāvasceti
(अन्योन्याभावश्चेति)।

Vastunaḥ samsargābhāvaḥ, yathā tejodravye śītasaṁsargābhāvamūlakaḥ. Ekatra vastuni vastvantarasya tādātmyābhāvamūlakaḥ. Idamidaṁ na bhavati iti pratītisākṣikobhāvonyonyābhāvaḥ. Yathā tejah pṛthvī na bhavati, pṛthvī tejo na bhavati ityādipratisākṣikobhāvaḥ

(वस्तुनः संसर्गाभावः यथा तेजोद्रव्ये शीतसंसर्गाभावमूलकः। एकत्र वस्तुनि वस्त्वन्तरस्य तादात्म्याभावमूलकः। इदमिदं न भवति इति प्रतीतिसाक्षिकोभावोन्योन्याभावः। यथा तेजः पृथ्वी न भवति पृथ्वी तेजो न भवति इत्यादिप्रतिसाक्षिकोभावः)

—P.B.

7. *Saṁsaragābhāvastrividhaḥ, prāgabhāvaḥ, pradhvaṁsābhāvaḥ, atyantābhāvaśceti*

(संसर्गाभावस्त्रिविधः प्रागभावः, प्रध्वंसाभावः, अत्यन्ताभावश्चेति)।

(a) Prāgabhāvaḥ: Kāryadravyotpatteḥ pūrvaṁ kāraṇadravye kāryadravyasyābhāvaḥ prāgabhāvaḥ. Yathā mṛttikāyām ghaṭābhāvaḥ

(प्रागभावः कार्यद्रव्योत्पत्तेः पूर्वं कारणद्रव्ये कार्यस्याभावः। यथा मृत्तिकायां घटाभावः)।

(b) Pradhvaṁsābhāvaḥ: Kāryadravye naṣṭe sati tat kāryadravya-syābhāvaḥ pradhvaṁsābhāvaḥ. Yathā ghaṭe naṣṭe sati ghaṭa- syābhāvaḥ

(प्रध्वंसाभावः कार्यद्रव्ये नष्टे सति तत्कार्यद्रव्यस्याभावः प्रध्वंसाभावः। यथा घटे नष्टे सति घटस्याभावः)।

(c) Atyantābhāvaḥ: Antaṁ pūrvaṁ uttaraṁ koṭi ca atikrānto yobhāvaḥ sotyantābhāvaḥ

(अत्यन्ताभावः अन्तं पूर्वं उत्तरं कोटिं च अतिक्रान्तो योभावः सोत्यन्ताभावः)।

Prāgabhāvasya pūrvakoṭihīnasyāpi uttarakoṭirbhavati, pradhvaṁsasya uttarakoṭi hīnasyāpi pūrva koṭirbhavati, kintu atyantābhāvasya kāpi koṭirna bhavati, sojanyovināśī ca. Ayaṁ tatra sthāne bhavati yatra tasya pratiyogī kadāpi na tiṣṭhati. Yathā tejasi śītasya bhāvaḥ

(प्रागभावस्य पूर्वकोटिहीनस्यापि उत्तरकोटिर्भवति, प्रध्वंसस्य उत्तरकोटिहीनस्यापि पूर्वकोटिर्भवति, किन्तु अत्यन्ताभावस्य कापि कोटिर्न भवति। सोजन्योविनाशी च। अयं तत्र स्थाने भवति, यत्र तस्य प्रतियोगी कदापि न तिष्ठति। यथा तेजसि शीतस्य भावः)

—P.B.

APPENDIX I

References

Acronyms	Book	Author/year/Publisher
J.K.	*Jñana Kośa*	S.V. Ketkar, 1922
V.G.V.	*Vaiśeṣika Siddhāntānāṁ Gaṇitīya Paddhatyā Vimarśaḥ*	N.G. Dongre, 1979, Research Institute, S.S. Vishwavidyalaya, Varanasi
V.S.	*Vaiśeṣika Sūtram*	Kaṇāda
V.N.	*Vatsyā yana Nyāya Bhāṣya*	
F.S.A.I.	*Founder of Sciences in Ancient India*	Satya Prakash, The Research Institute of Ancient Scientific Studies, 1965, New Delhi
W.U.E.	*The World University Encyclopedia*	Publishers Company Ink., Washington, 1965
S.S.	*Sāṇkhya Sūtram*	
N.K.T.	*Nyāya Kandalī Tīkā*	
P.B.	*Praśastapāda Bhāṣyam*	1894
N.S.	*Nyāya Sutram*	Gautama
P.S.S.S.	*Prācīna Śilpasāra*	
(–)	*Physics, N.C.E.R.T.*	Boston, 1966

A.K.	*Amarakośa*	
M.M.	*Matter and Man*	Peace Publication, Moscow
T.U.	*Taittirīyopaniṣad*	
B.P.	*Bhāṣā Pariccheda*	
L	*Līlāvatī*	Bhāskarācārya
K.U.	*Kiraṇāvalī*	Udayanācārya
S.	*Sūryasiddhānta*	
B.S.S.	*Samarāṅgaṇa Sūtradhāraḥ*	Bhojadeva
K.A.	*Kauṭilīya Artha Śāstraṁ*	Ramateja Śastrī
–	*Golapāda*	Āryabhaṭa
–	*Properties of Matter*	C.J.L. Wagstaff, London 1934
–	*Muktāvalī*	
	Pratyāsthatā	(N.G. Dongre) Hindi Visvakosa, Nagari Pracarani Sabha, Varanasi
–	*Golapādādhāyaḥ.*	Bhāskarâcārya
–	*Waves and Oscillation*	N.G. Dongre and C.K. Bhattacharya, Viswa-vidyalay Prakashan, Varanasi.

APPENDIX II

List of Modern and Oriental Sciential Terms

English	**Sanskrit**
Absence	*Abhāva*
Absence of identity	*Anyonyābhāva*
Absence of relation	*Saṁsargābhāva*
Absolute absence	*Atyantābhāva*
Acceleration	*Gaticaya*
Acoustical sound	*Kṣaṇika śabda*
Adhesion	*Sneha*
Analogue	*Upamāna*
Aphorism	*Sūtra*
Area	*Kṣetra*
Arrow	*Śara*
Astronomy	*Jyotiṣa*
Atom	*Aṇu, Pīlū, Paramāṇu*
Aversion	*Dveśa*
Average	*Madhya*
Ball	*Kanduka*
Basic material	*Bhoutika*
Basic physical quantity	*Dravya*
Beaker	*Caṣaka*
Cause for creation	*Dravyāraṁbhakatva*
Callipers	*Vyāsamāpaka*
Chemical change	*Pāka*

Chemical product	*Pākaprabhava*
Chemical reaction	*Pākakriyā*
Chord	*Jīvā*
Circle	*Vṛtta*
Circumference	*Paridhi*
Cognition	*Buddhi, Sanjñana*
Cohesion	*Dravatva*
Collision	*Abhighāta*
Colloidal particle	*Trasareṇu*
Colour	*Rūpa*
Commentary	*Bhāṣya*
Complete destruction	*Pralaya*
Concomitance	*Samavāya*
Conjunction	*Saṁyoga*
Consequent absence	*Praddhvaṁsābhāva*
Consonant	*Varṇa*
Continuum	*Vibhu*
Copper	*Tāmra*
Cosmic degeneracy	*Adharma*
Cosmic order	*Dharma*
Creation	*Sṛṣṭi*
Curved surface	*Jāla*
Cylinder	*Vṛttakhātapātra*
Decomposition	*Bhaṅga*
Dependent	*Ādheya*
Desire	*Icchā*
Diameter	*Vyāsa*
Difference	*Vaidharmya*
Disjunction	*Vibhāga*
Divider	*Kārpāsaka*
Dust particle	*Raja*
Element	*Apara Sāmānya*
Energy (radiant)	*Teja*
First term	*Mukha*
Flask	*Vardhanī*

Force-elastic	*Sthitisthāpakatā Saṁskāra*
Force-emotional	*Bhāvanā Saṁskāra*
Force-mechanical	*Vega Saṁskāra*
Gas	*Vāyu*
General properties	*Sāmānya guṇāḥ*
Graduated	*Aṁśānkita*
Gravity	*Gurutva*
Hydrogen	*Udāna*
Ideal	*Sāṁsiddhika*
Ideal states of matter	*Mahābhūta*
Impact	*Abhighāta*
Independent	*Ādhāra*
Inference	*Anumāna, niṣkarṣa*
Invisible	*Adṛṣṭa*
Knowledge of Self	*Ātmajñāna*
Last term	*Antya*
Length	*Dairghya*
Line	*Rekhā*
Linear motion	*Gamana*
Liquid	*Ap*
Logic	*Nyāya*
Mass	*Pārthivamāna*
Materialistic	*Bhoutika*
Material wave	*Anāhatanāda*
Mathematical operation	*Gāṇitika karma*
Mathematics	*Gaṇita*
Measurement	*Māpana, Parimeyatva*
Mechanical action	*Prayatna*
Medium	*Vāhaka*
Mercury	*Pārada*
Mind	*Mana*
Molecule	*Dvyaṇuka*
Momentum	*Karma*
Motion	*Karma*

Motion against gravity	*Utkṣepaṇa*
Motion along gravity	*Avakṣepaṇa*
Solid	*Pṛthvī*
Sorrow	*Duḥkha*
Soul	*Ātmā*
Space (length vector)	*Dik*
Specific (ultimate partlessness)	*Viśeṣa*
Specific properties	*viśeṣa guṇāh*
State of a matter	*Bhūta*
Square	*Varga*
Subset	*Parāpara sāmānya*
Taste	*Rasa*
Temperature	*Sparśa*
Temporal	*Naimittika*
Term	*Pada*
Thread	*Tantu*
Time	*Kāla*
Ultimate	*Ātyantika*
Unit	*Parimāṇa*
Universal set	*Para Sāmānya*
Velocity	*Gati*
Volition	*Prayatna*
Volume	*Ghana (avakāśa)*
Wave aspect	*Śabda*
Zinc	*Dastā*

Lasertypeset at Ideal Publishing Solutions, Delhi and
printed at J.J. Offset Printer, Noida

Indian civilization was one of the most advanced and sophisticated of all the early civilizations. Its dynamic and progressive impact had a major influence in the evolution of other civilizations. The book primarily deals with the impact of ancient Indian science, particularly in the field of physics and thereby presents evidence which shows that scientific concepts like Newton's Laws of Motion were already prevalent at that time in India. Moreover, the book brings to fore the systematic and scientific methodology followed by ancient Indian philosophers. Drawing mainly from available extant literature, particularly *Vaisesika Darshan*, one of the six well-known systems of Vedic philosophy propounded by Anulukya, more popularly known as Kanada, the book draws a parallel between the scientific temper of the past and today. The book may be of interest to students, scholars and general readers who are interested in the achievements of ancient Indian science.

nbt.india
एकः सूते सकलम्

NATIONAL BOOK TRUST, INDIA

ISBN 8123779739

16170452